

# Exotics and BSM in ATLAS and CMS



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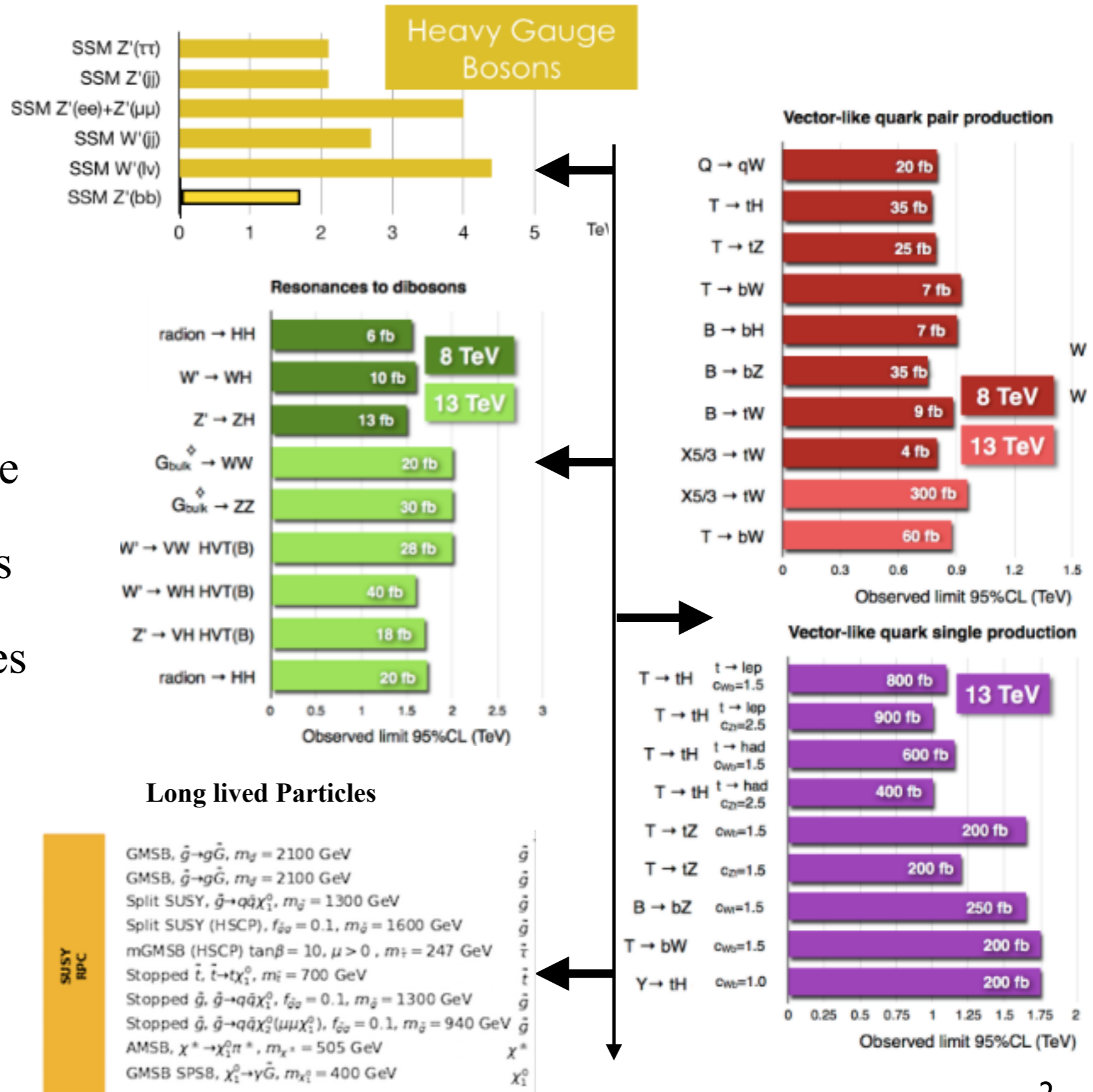
On Behalf of ATLAS and CMS Collaborations

Corfu2019, Greece

September 6, 2019

# Outline

- ❖ Introduction
- ❖ Exotica searches
  - ◆ Heavy Bosons
  - ◆ Diboson Resonance
  - ◆ Vector Like Quarks
  - ◆ Long-lived Particles
- ❖ Conclusion



# Introduction

- **Discovery of a scalar boson consistent with SM**

## Higgs

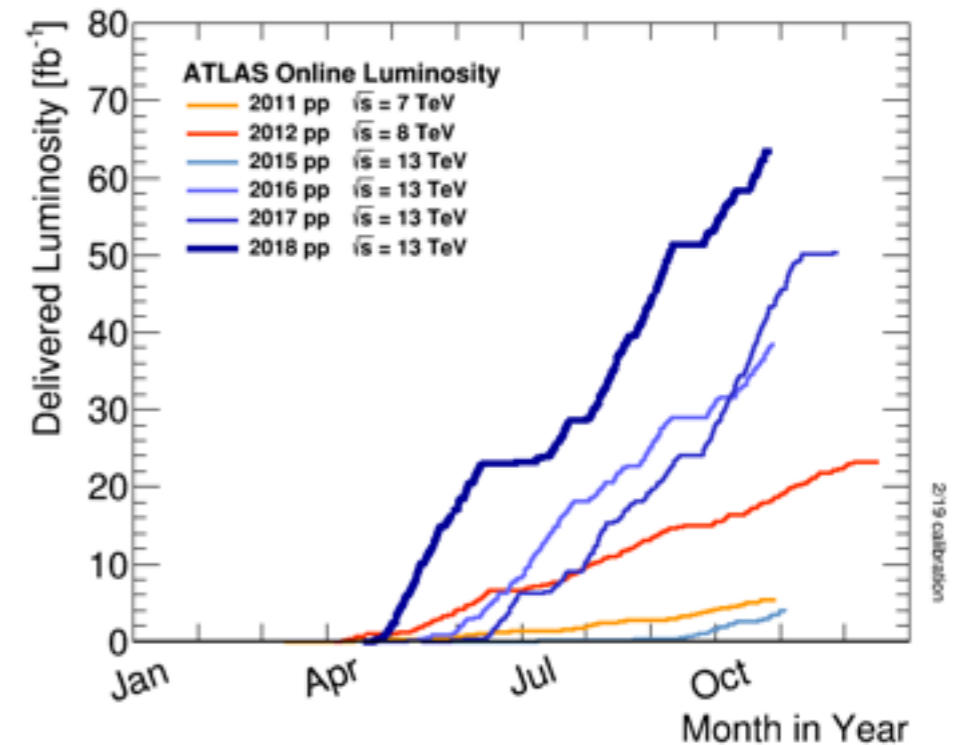
- Is it SM Higgs or something else ?
- new window for physics beyond SM

- **Exotica searches**

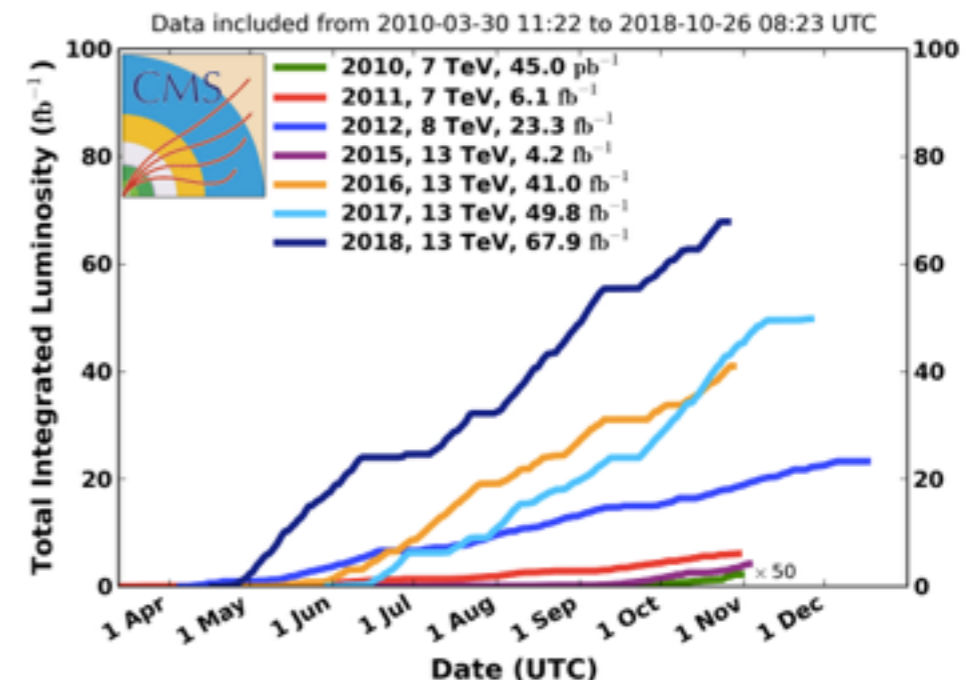
- cover wide range of final states
- numerous models (extension of SM):
  - hierarchy problem
  - neutrino mass
  - dark matter

- **Successful Operation of LHC Run 2 (13TeV)**

- both ATLAS and CMS:  $\sim 140\text{fb}^{-1}$  data for physics
- Ideal place for exotica searches



CMS Integrated Luminosity Delivered, pp



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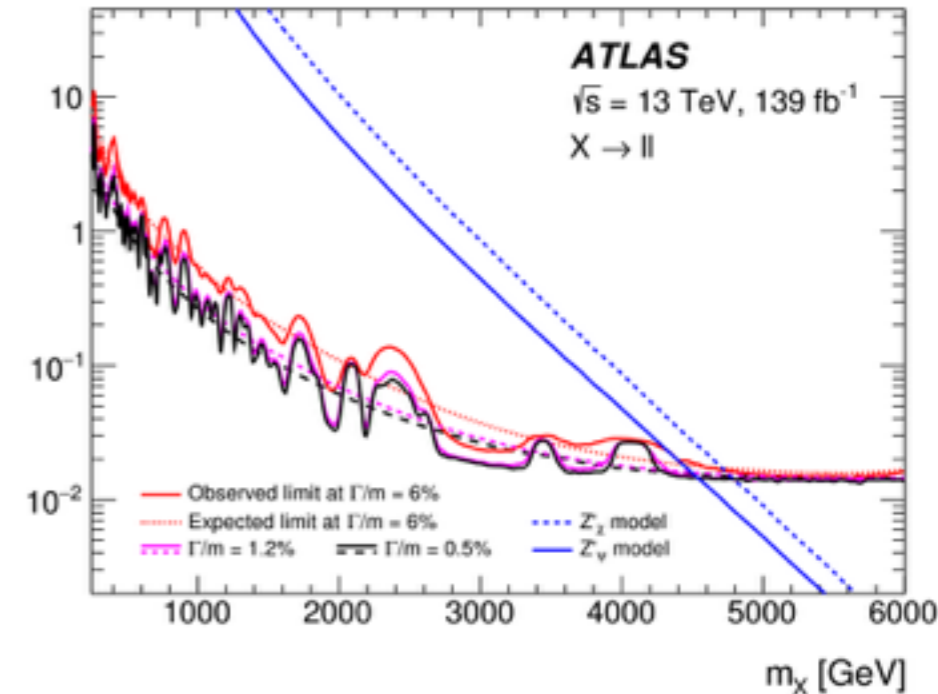
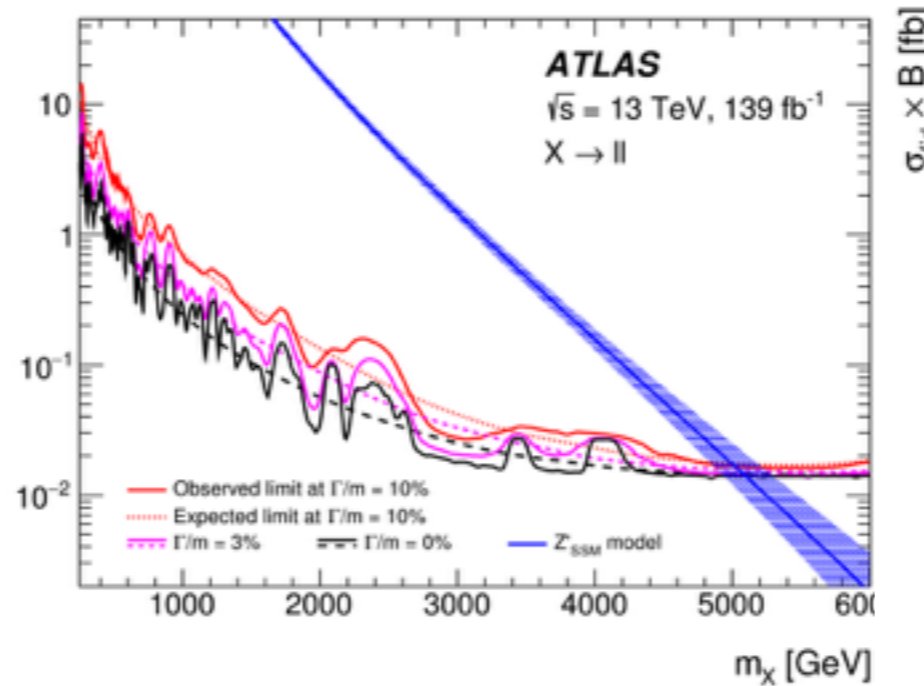
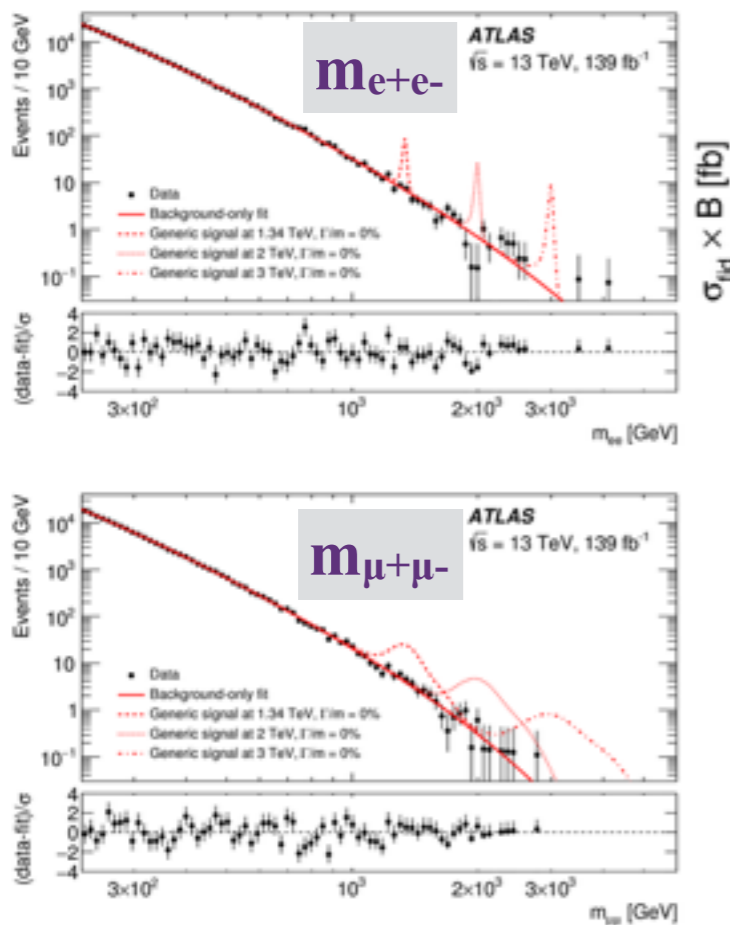
# Heavy Boson Search

— Leptons final state

# $Z' \rightarrow l^+ l^-$

- Generally, all new particles that can decay to dilepton called  $Z'$
- Many BSM theories predict  $Z' \rightarrow l^+ l^-$ 
  - extension of SM in Grand Unification (e.g  $Z'_\psi$ )
  - some SUSY models predict new spin-0 resonance
  - sequential SM predict  $Z'_{\text{SSM}}$

Phys.Lett.B 796(2019)68



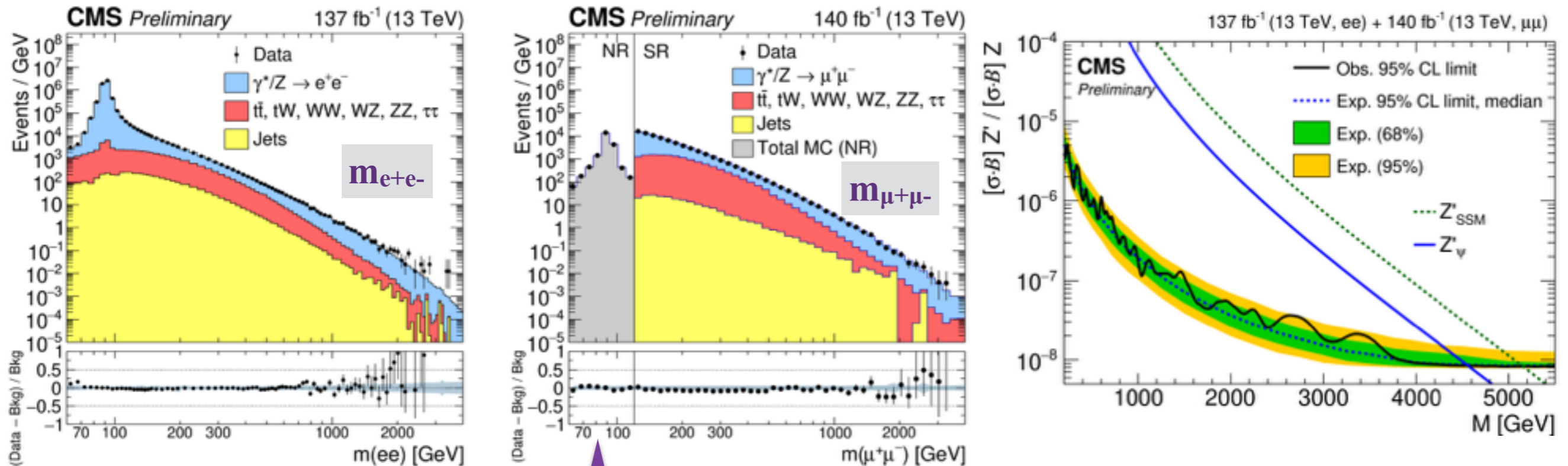
Good modelling for all data up to 3TeV.

Limit reach 5TeV for  $Z'_{\text{SSM}}$  and 4.5 TeV for  $Z'_\psi$  by all Run 2 data.

# $Z' \rightarrow l^+ l^-$

- Generally, all new particles that can decay to dilepton called  $Z'$
- Many BSM theories predict  $Z' \rightarrow l^+ l^-$ 
  - extension of SM in Grand Unification (e.g  $Z'_\psi$ )
  - some SUSY models predict new spin-0 resonance
  - sequential SM predict  $Z'_{\text{SSM}}$

CMS-PAS-EXO-19-019



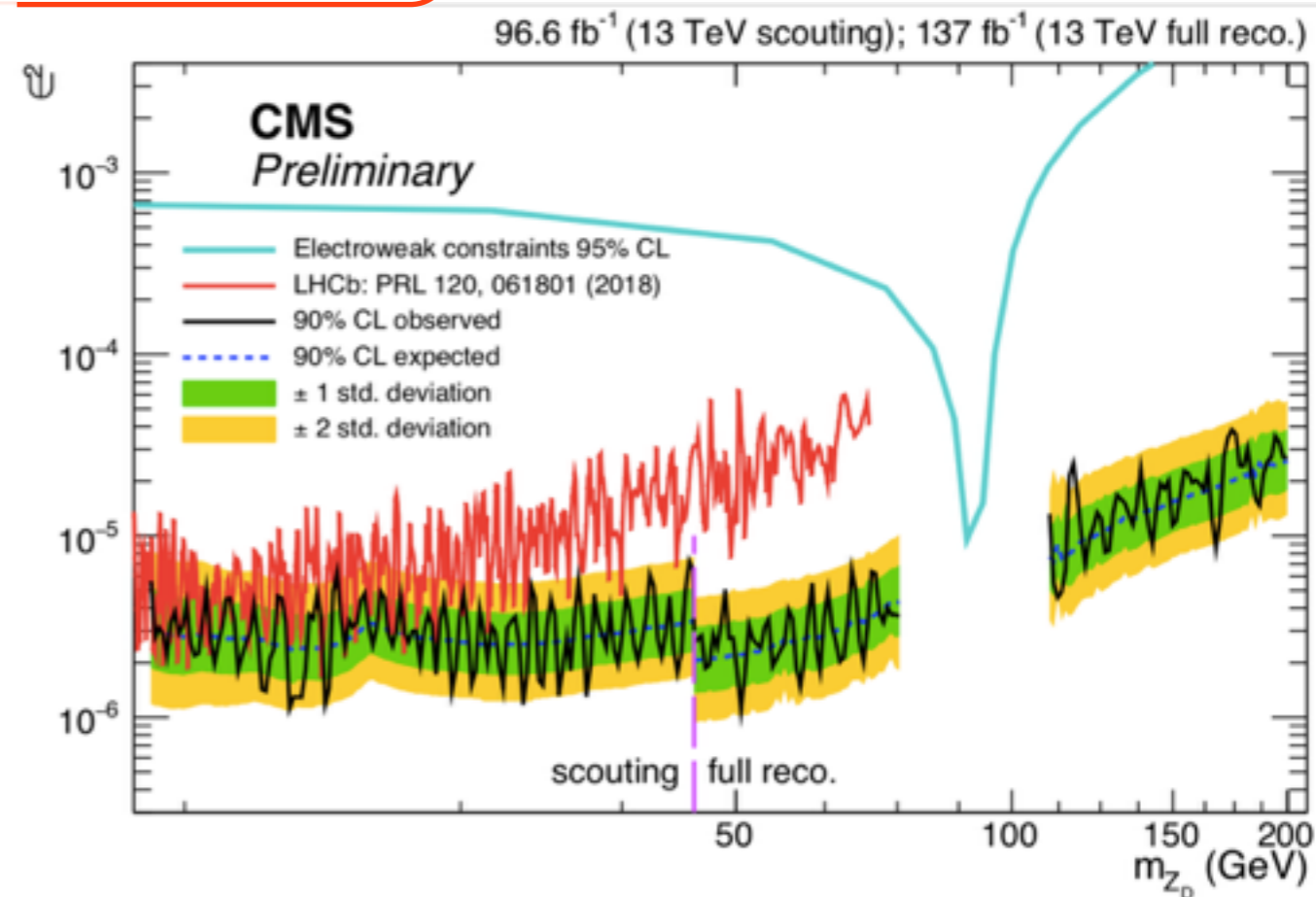
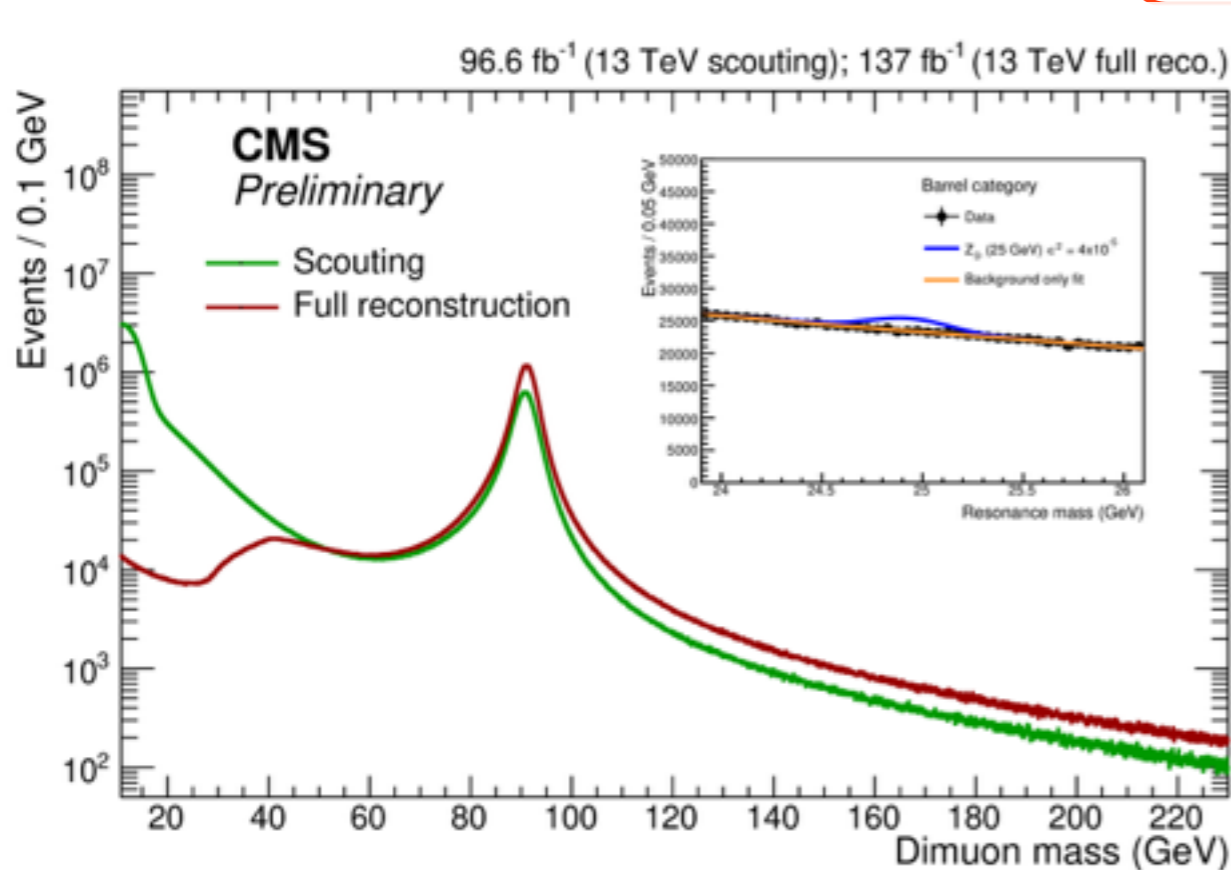
Prescaled muon trigger (27GeV) applied for  $m_{\mu^+\mu^-} < 120\text{GeV}$  online.

Limits similar as ATLAS: 5.15TeV for  $Z'_{\text{SSM}}$  and 4.56 TeV for  $Z'_\psi$

# di-muon low mass

- Search for resonance in  $m_{\mu+\mu^-}$  range of [45, 75] & [110, 200] GeV with full reco data ( $139 \text{ fb}^{-1}$ )
  - $p_T > 20(10) \text{ GeV}$  for 2 OS muons
- Search for bumps in  $m_{\mu+\mu^-}$  range of [11.5, 45] GeV with scouting data ( $\sim 100 \text{ fb}^{-1}$ )
  - reduced trigger information, only muon related data is partially recorded.
  - offline muon  $p_T > 4 \text{ GeV}$

CMS-PAS-EXO-19-018

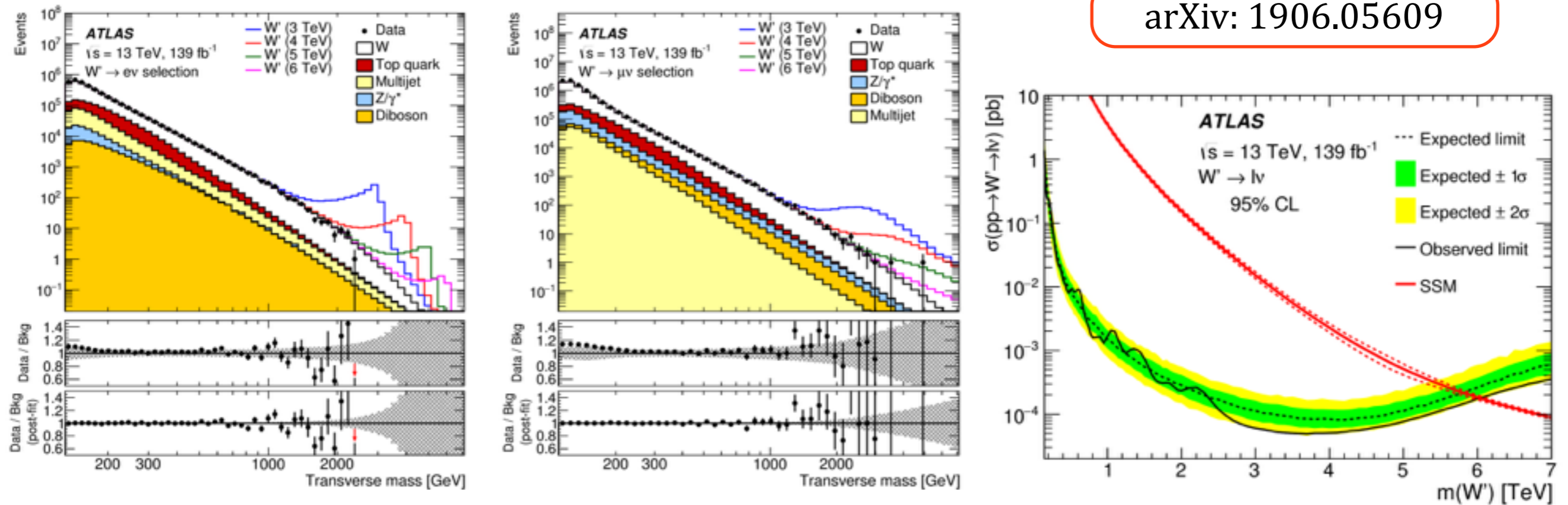


The most stringent limits for dark photon in the low  $m_{\mu+\mu^-}$  region.

# $W' \rightarrow l\nu$

- Search for heavy boson with lepton+MET signature.
- Look for excess on the transverse mass distribution.
- Dominant backgrounds coming from:  $W$ +jets, Top, QCD, Z, multi-bosons

arXiv: 1906.05609



Assuming  $W'$  boson with the same coupling as the SM  $W$  boson,  
 $W'$  masses below 6 TeV are excluded at 95% CL in SSM.



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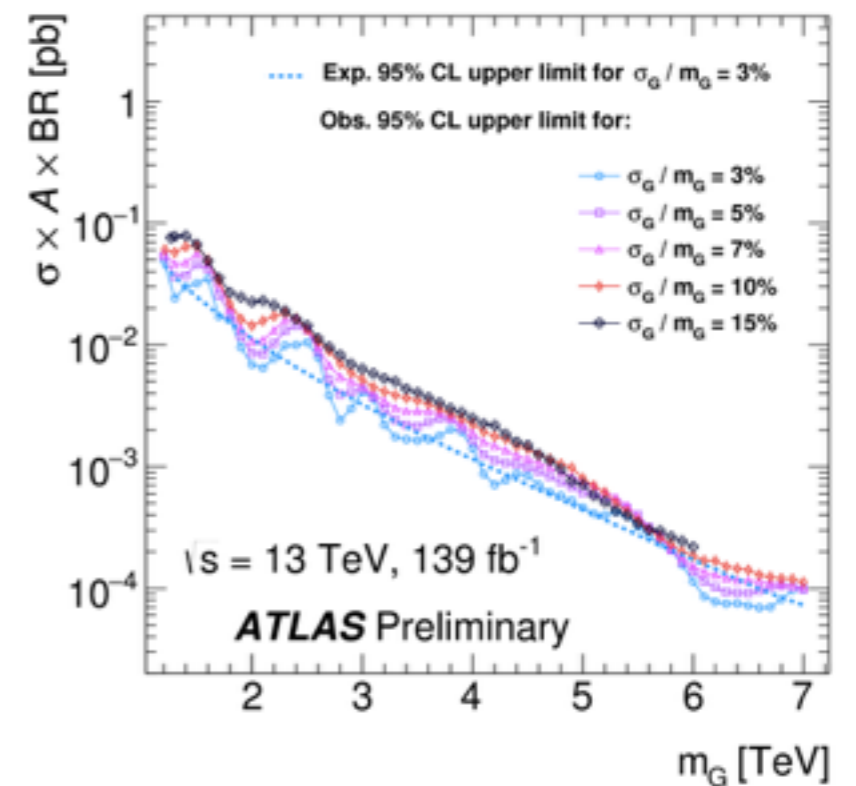
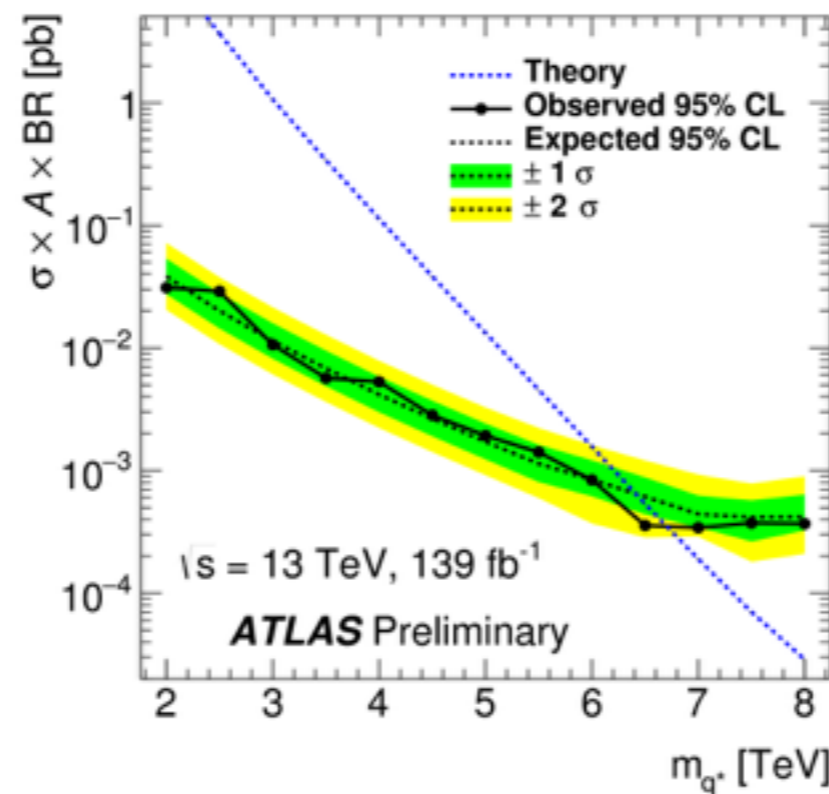
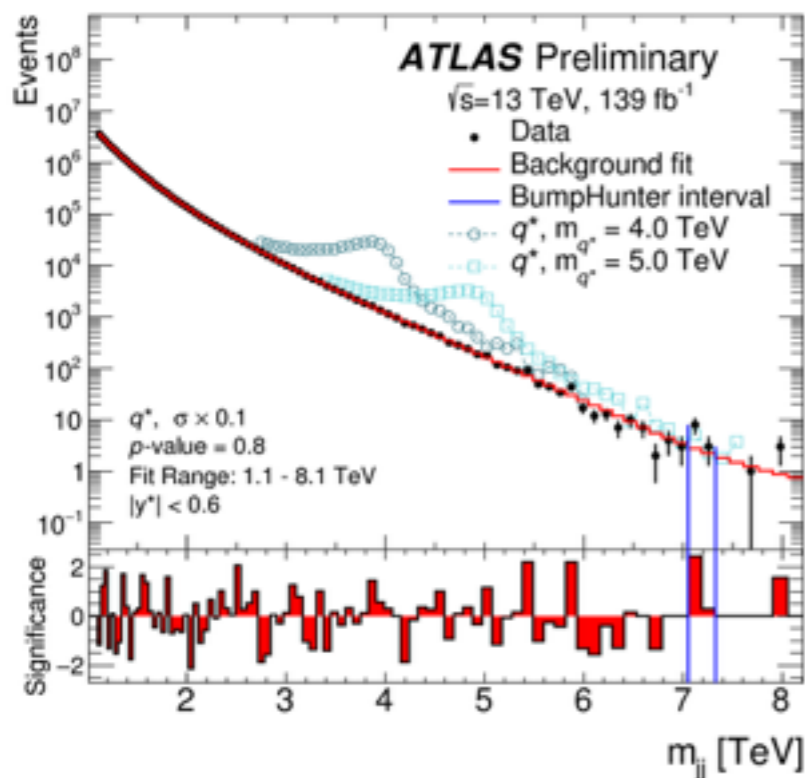
# Heavy Boson Search

— Dijet final State

# Di-jet resonance

- Probe numerous BSM models: String, Axiguons/Colorons, Color-octet scalar,  $W'/Z'$  bosons, RS ...
- Search for bumps on the smoothly falling di-jet invariant mass spectrum.

ATLAS-CONF-2019-007



No significant excess observed.

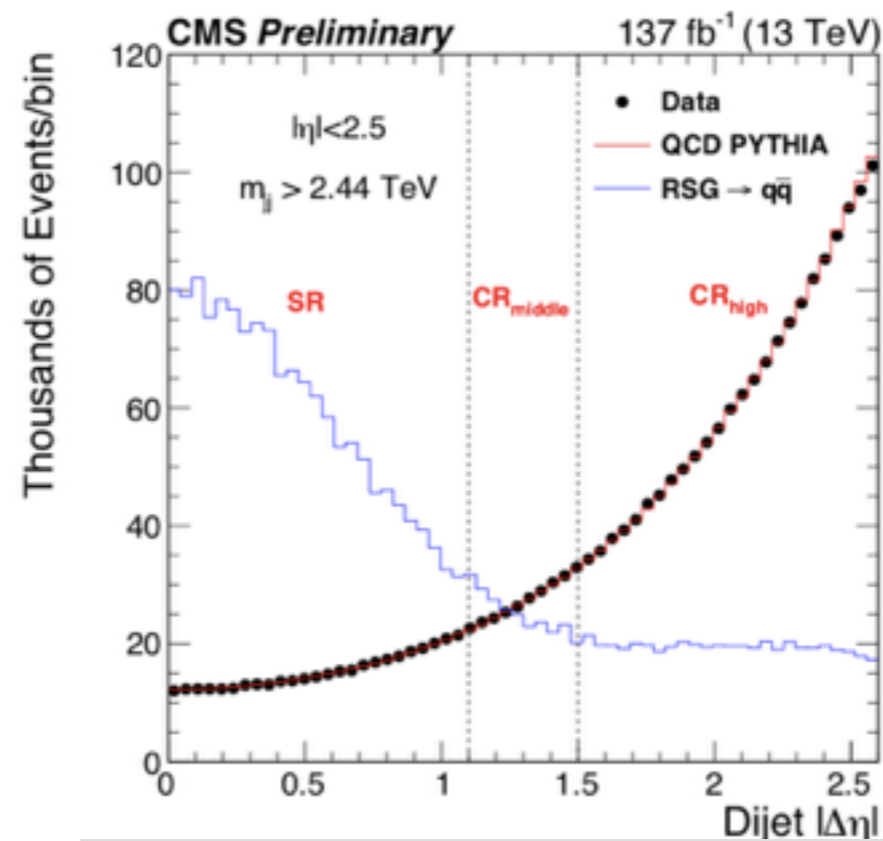
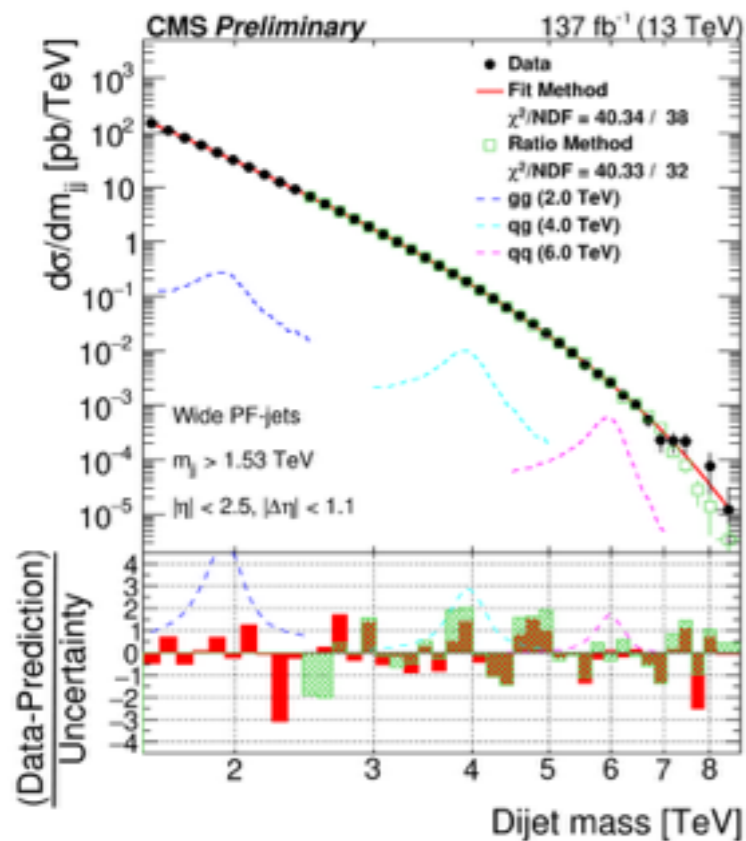
Mass limit of  $q^*$  up to 6.7 TeV with full Run 2 data.

Also look for Gaussian shaped signal with different Relative Width Hypothesis.

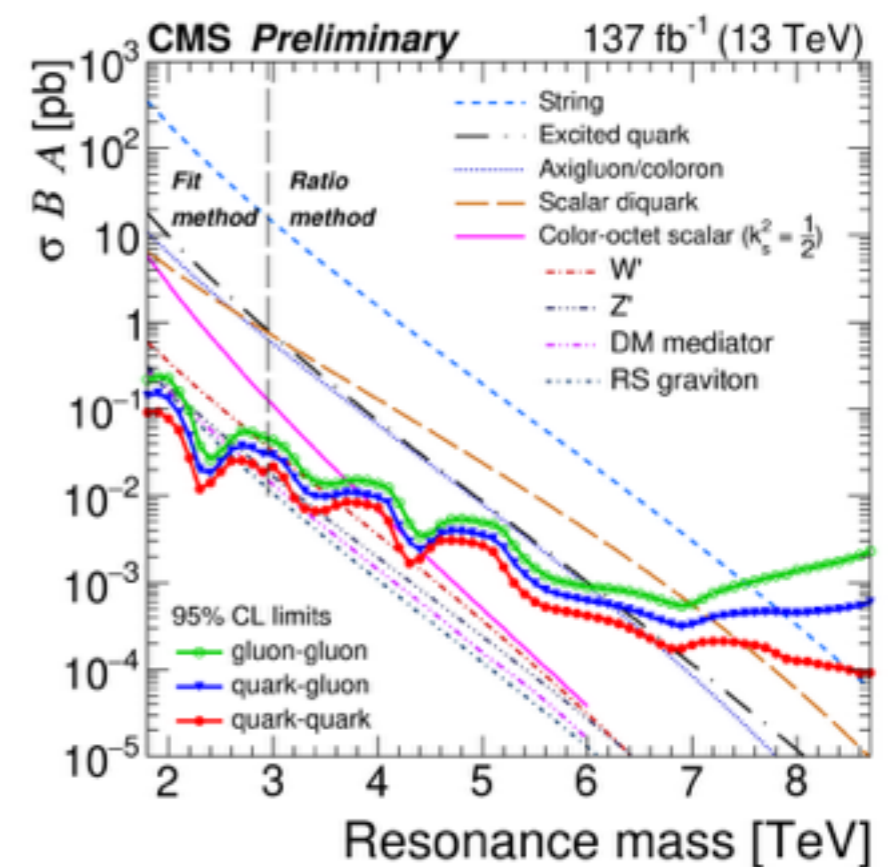
# Di-jet resonance

- Probe numerous BSM models: String, Axiguons/Colorons, Color-octet scalar,  $W'/Z'$  bosons, RS ...
- Search for bumps on the smoothly falling di-jet invariant mass spectrum.

CMS-PAS-EXO-19-012



Introduce two CRs to constrain the bkg.  
Big improvement w.r.t fit method in SR alone.



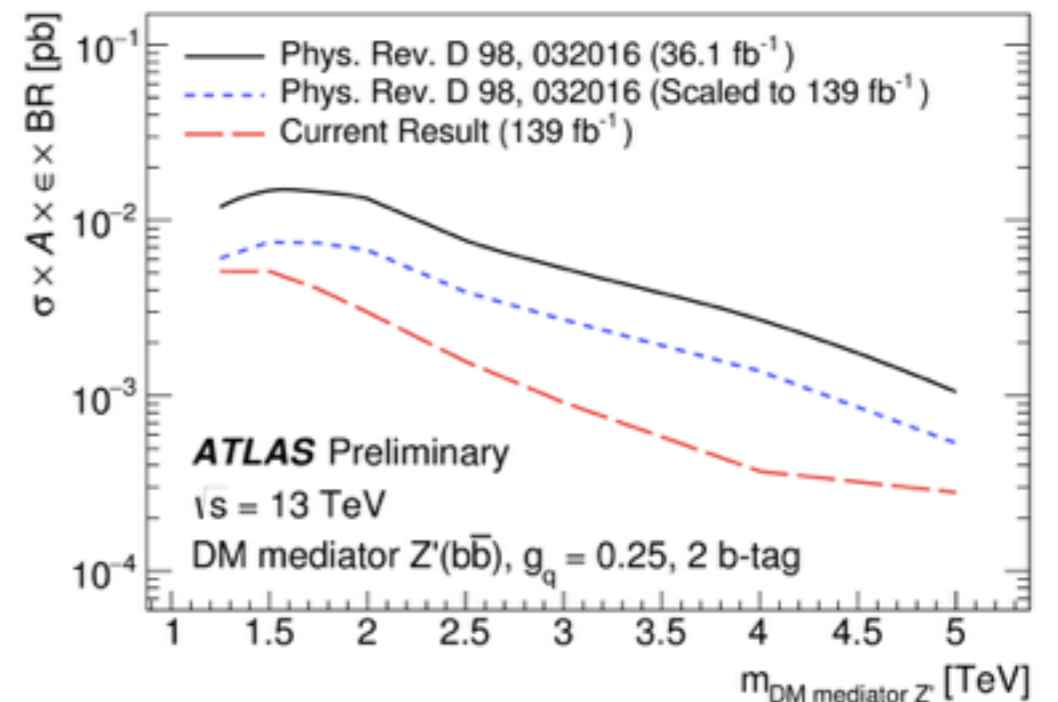
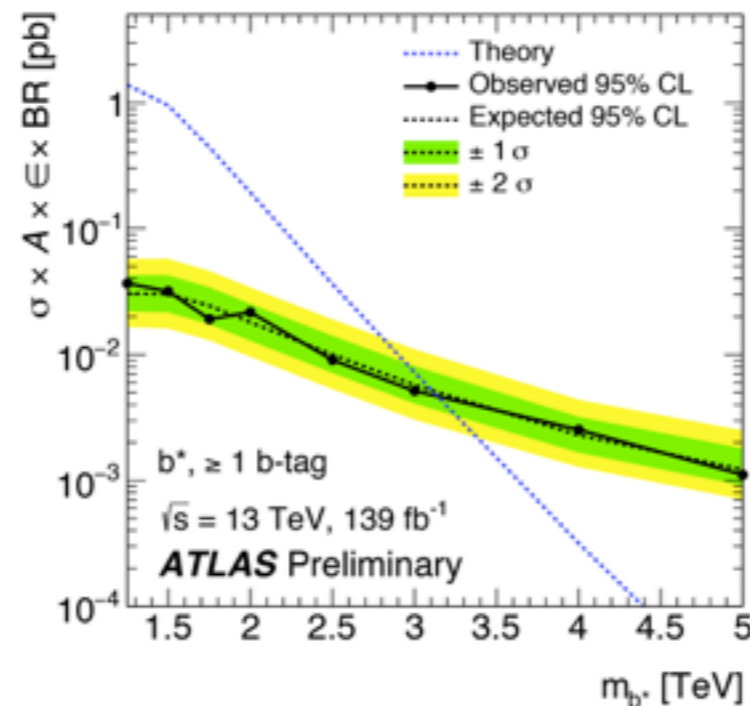
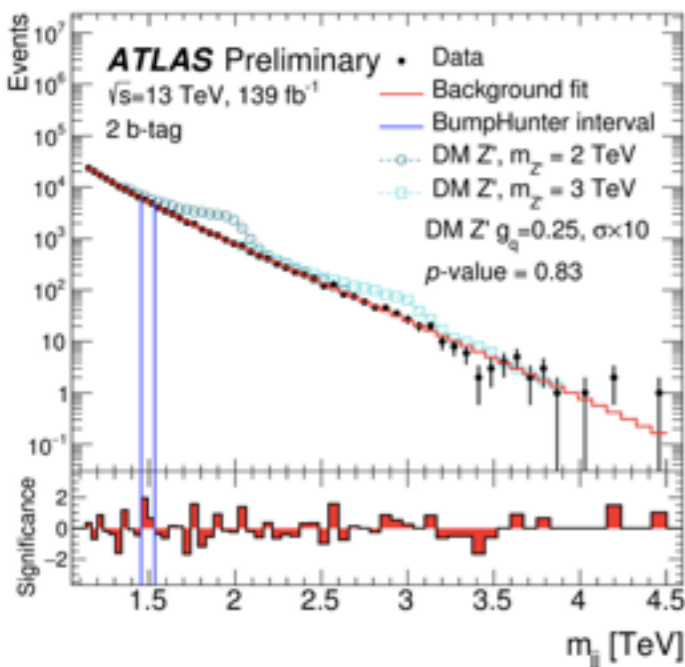
Excellent modelling of data!

Mass limits up to 7.9 TeV for different models.

# Di-bjet Resonance

- Test on BSM models:  $b^*$ , DM  $Z'(bb)$ , KK  $G(bb)$ , SSM  $Z'(bb)$
- Use b-tagging, categories based on the # of b-tagged jets:  $\geq 1$  b-tag, 2 b-tags
- First use new Deep Learning for B-tagging algorithm
  - Significantly improve the sensitivity (a factor of 1~3.7)

EXOT-2019-03



Good agreement between Data/MC(bkg only).

Limit moves up to 3.2 TeV for  $b^*$ .

		observed	expected
1b	$b^*$	3.2 TeV	3.1 TeV
	DM mediator $Z'$ , $g_q = 0.20$	2.8 TeV	2.8 TeV
2b	DM mediator $Z'$ , $g_q = 0.25$	2.9 TeV	3.0 TeV
	SSM $Z'$ ,	2.7 TeV	2.7 TeV
	graviton, $k/\overline{M}_{\text{PL}} = 0.2$	2.8 TeV	2.9 TeV

# Low Mass Dijet Resonance

● High Mass:  $\sim 1.5 - 8$  TeV

Standard trigger (jet trigger or Large  $H_T$ )

● Medium Mass:  $\sim 0.4 - 2$  TeV

Dedicated b-trigger or jet trigger

● Low Mass:  $\sim 0.2 - 1$  TeV

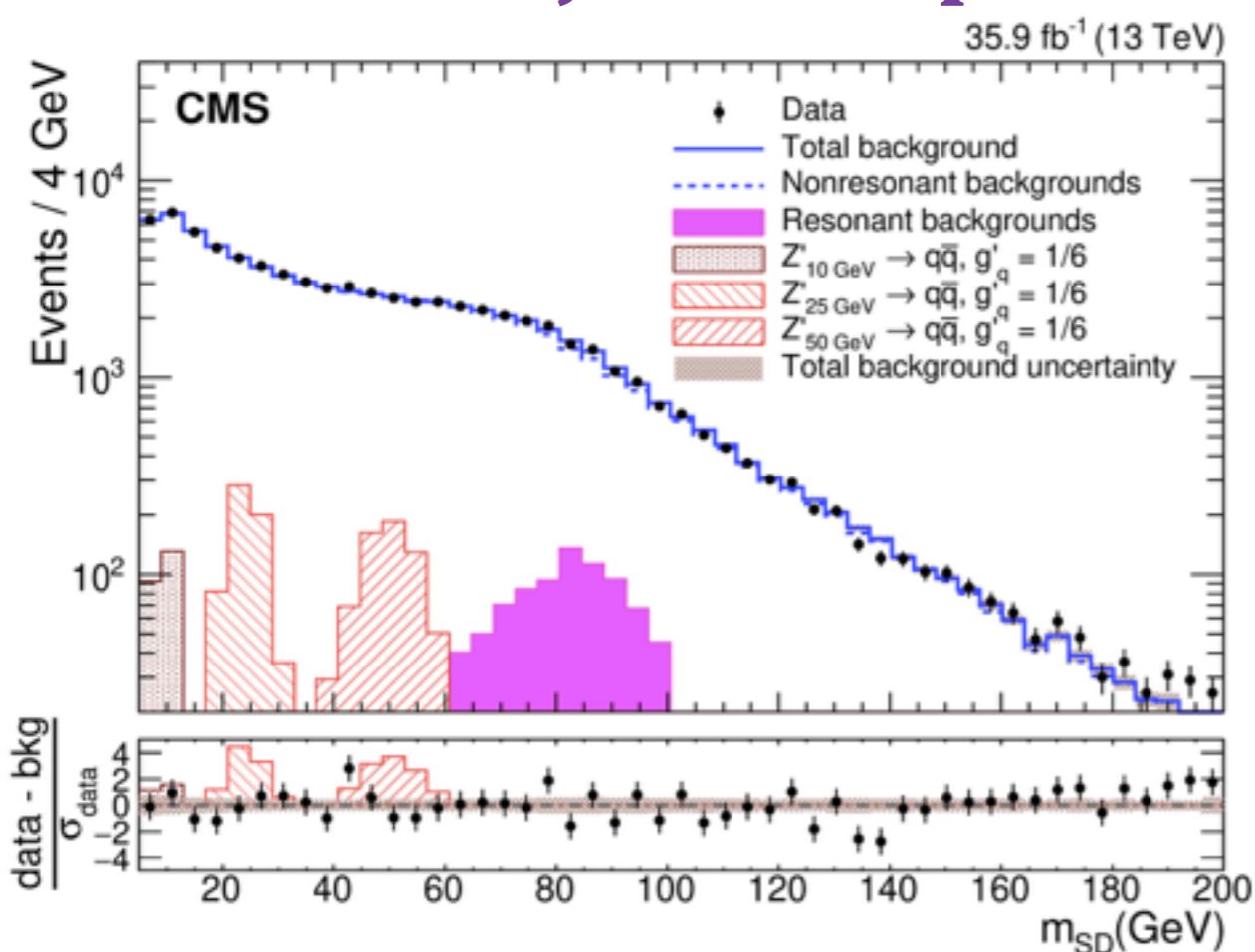
Dijet + ISR (**trigger!**)

● Very Low Mass:  $\sim 10 - 200$  GeV

Boosted Dijet + ISR (**trigger!**)

## Boosted Dijet + ISR photon

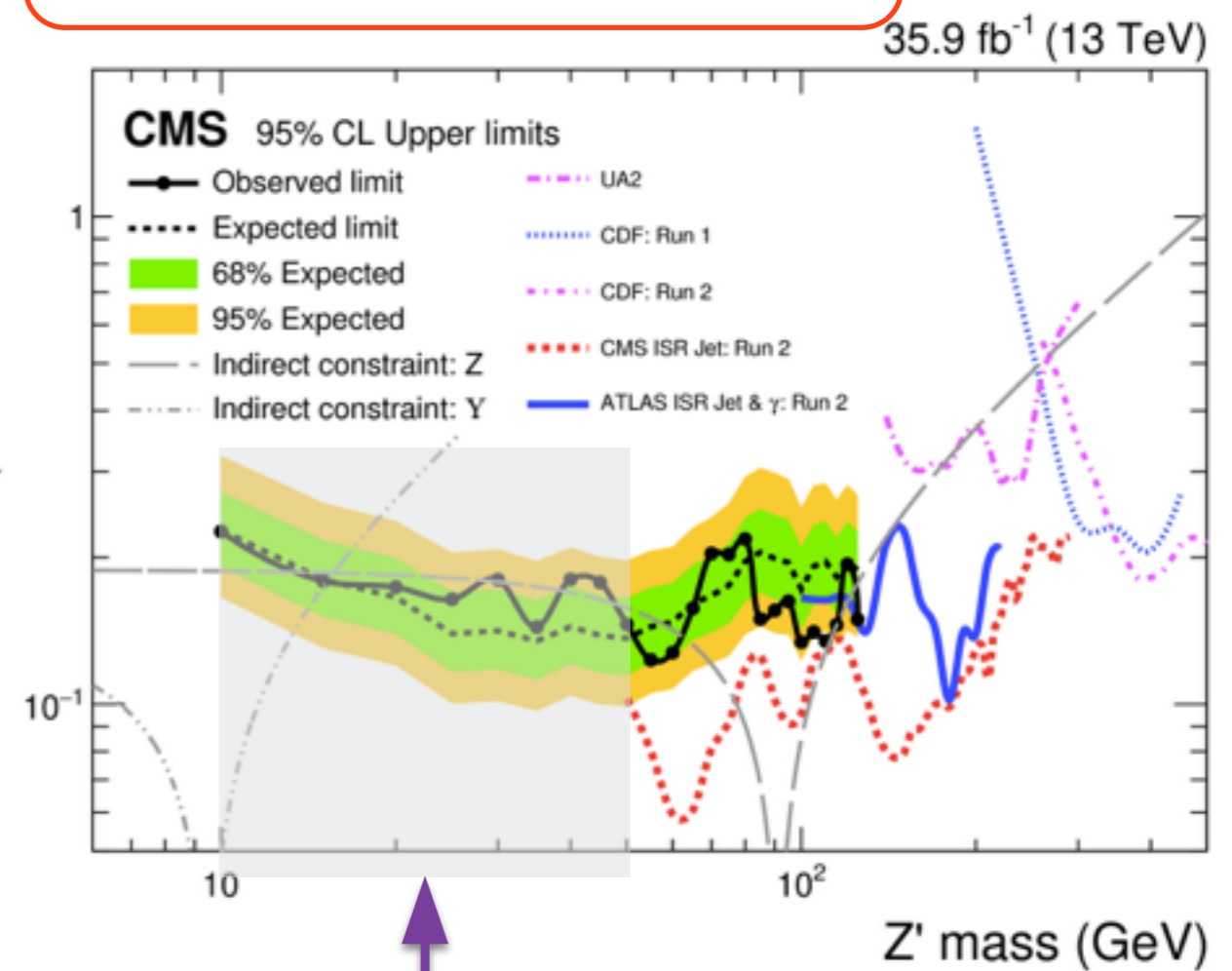
arXiv:1905.10331



Resonant bkg normalised from CR.

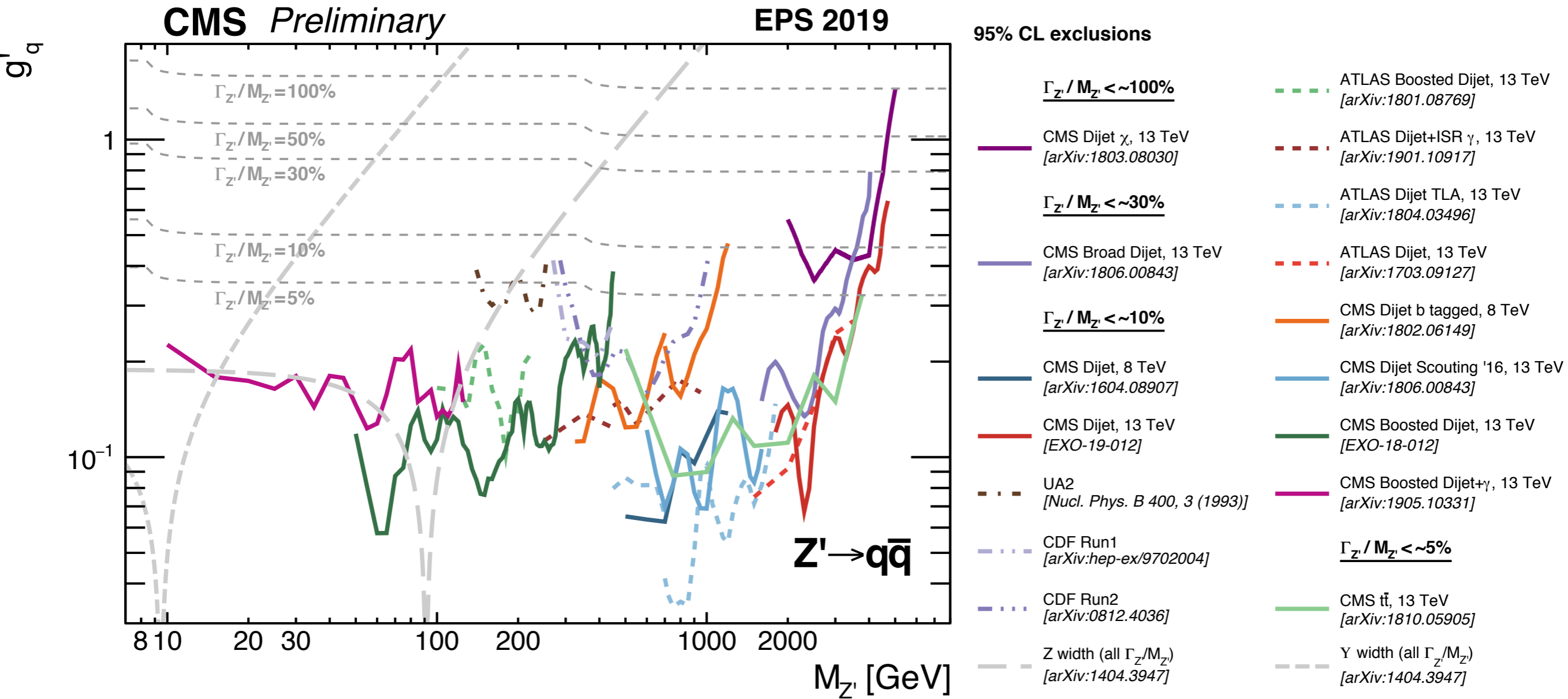
Non-Resonant bkg estimated from fit.

$g'_q$  coupling strength



First limits for dijet mass < 50 GeV with direct search in LHC.

# di-jet Resonance Summary plot



# Diboson Resonance

- Rich program of diboson resonance search

- Spin 0:  $S/H \rightarrow WW/ZZ$ : extended Higgs sectors, scalar singlet

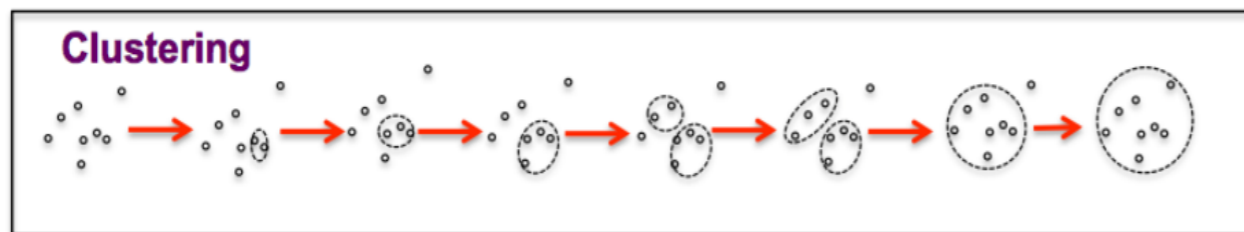
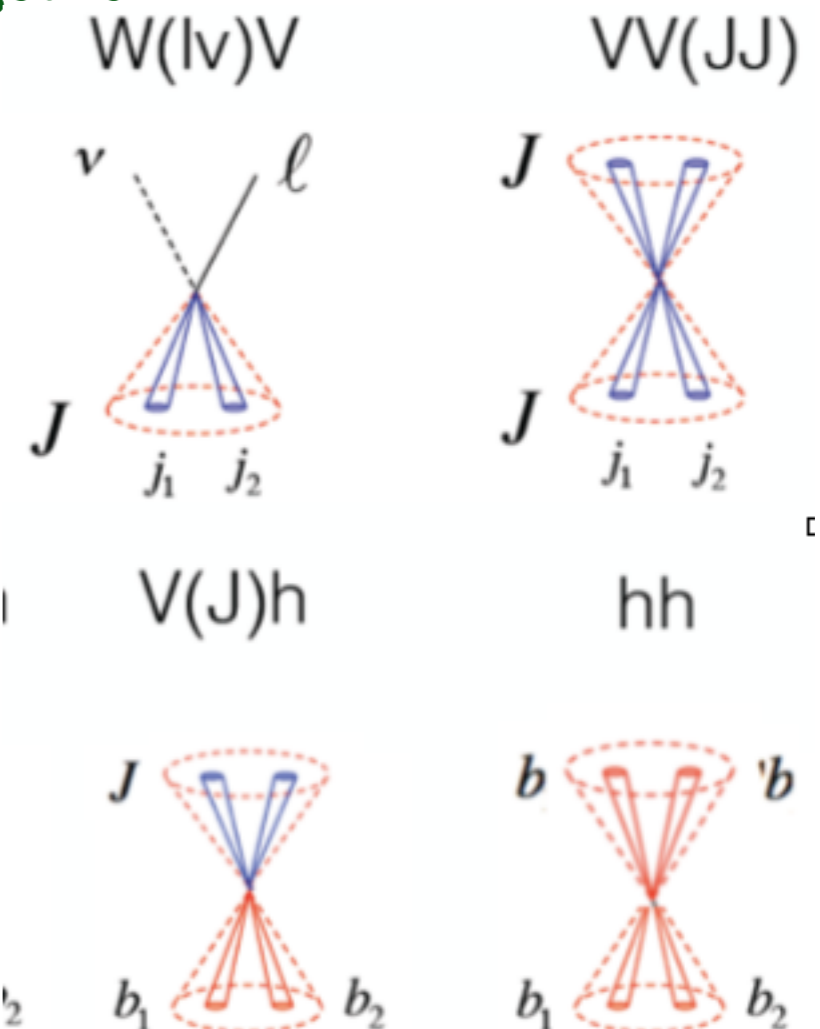
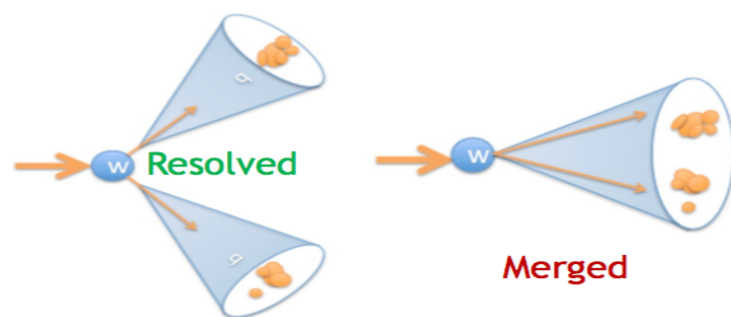
- Spin 1:  $V' \rightarrow VH/VV$ : Heavy Vector Triplet

- Spin 2:  $G^* \rightarrow VV$ : Extra dimensions

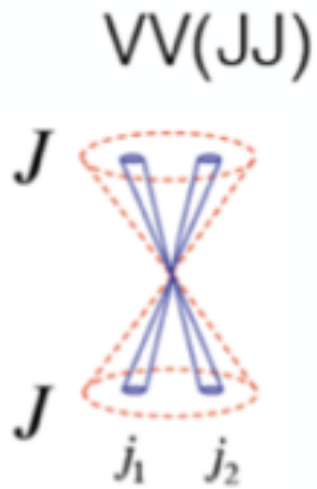
- Unable to cover all the final states in this talk. Only select a recent analysis.

- Highly boosted  $W/Z/H$  decay products are merged together

- Use jet sub-structure algorithm to tag boosted object

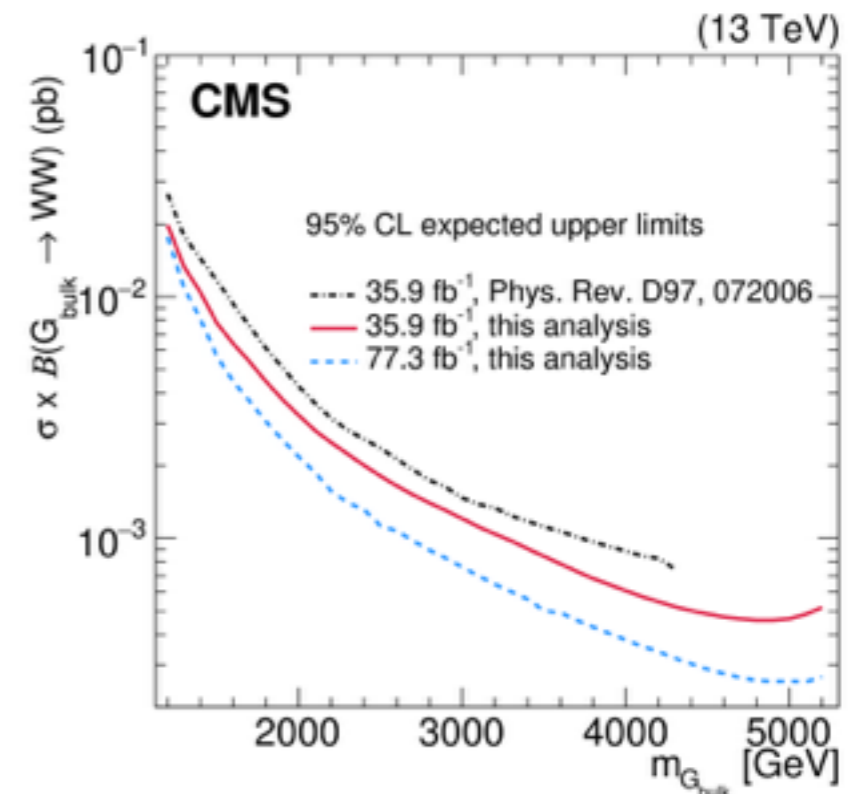
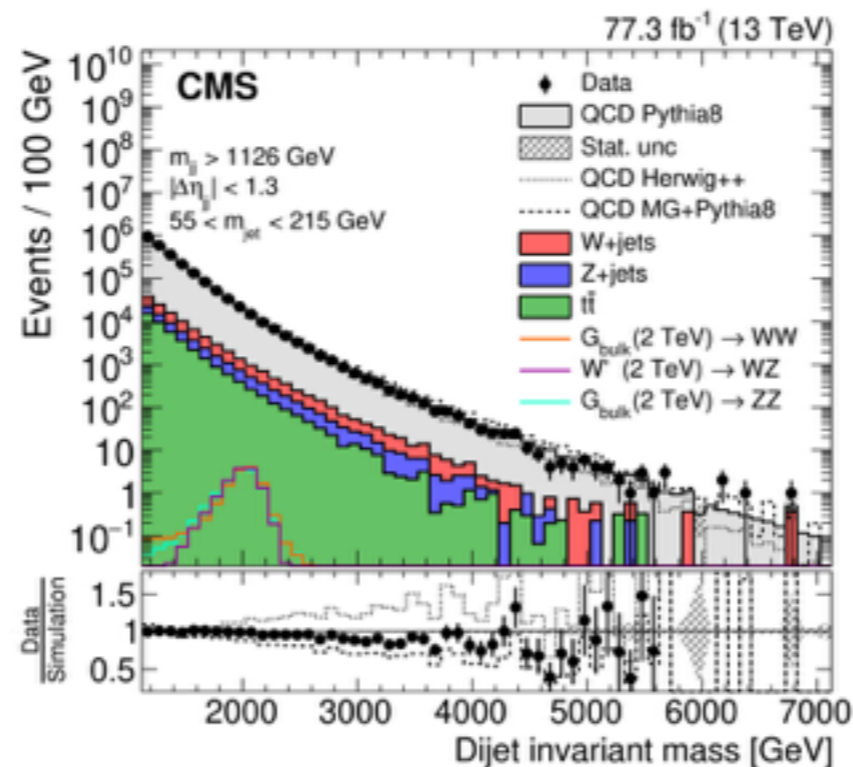
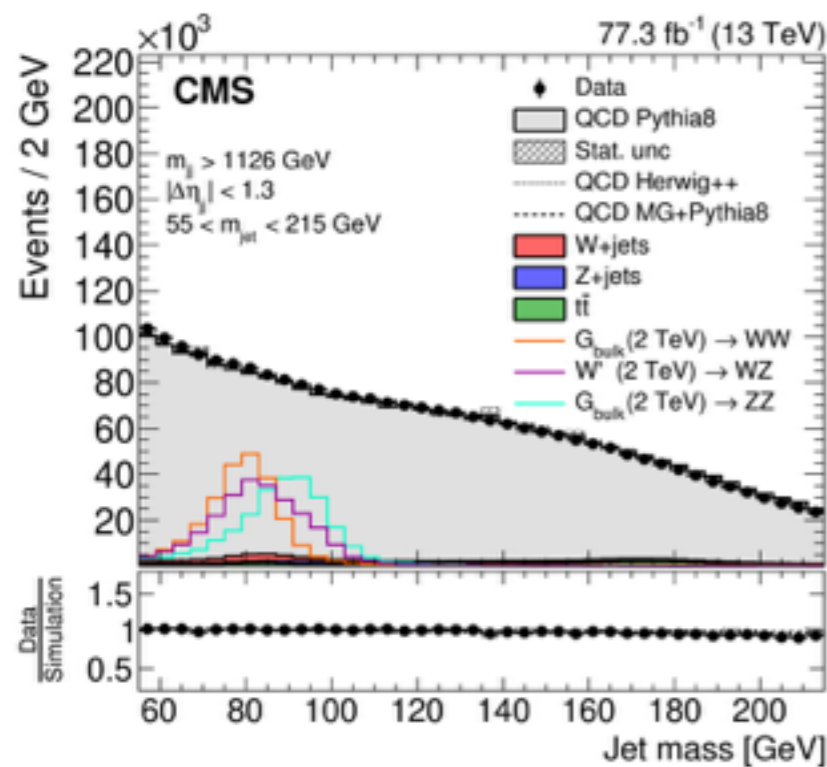


# “Dijet” —— $WW/WZ/ZZ$ Fully Hadronic decay



- Focus on the potential resonances with mass above 1.2 TeV,  $W/Z$  boson expected to be collimated into a fat jet
- Novel method: three-dimensional maximum likelihood fit of two jets masses and the dijet invariant mass: improve sensitivity by **~30%** w.r.t previous methods.

CMS-PAS-B2G-18-002

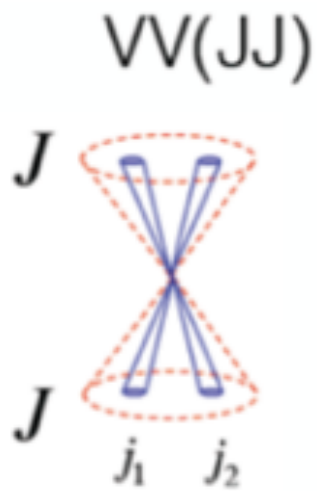


**No excess above the standard model background!**

**Exclude spin-1  $W'$  and  $Z'$  with masses lower than 3.8 TeV and 3.5 TeV respectively.**

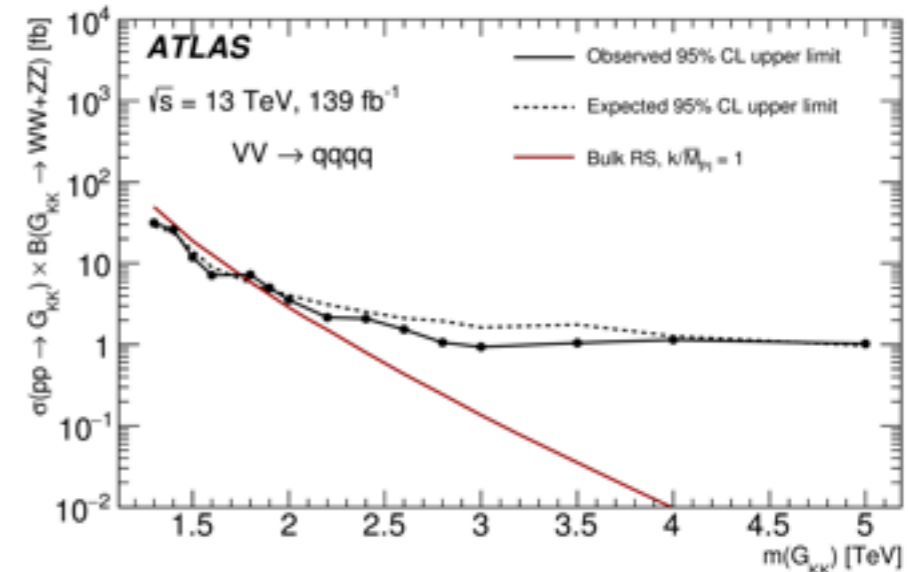
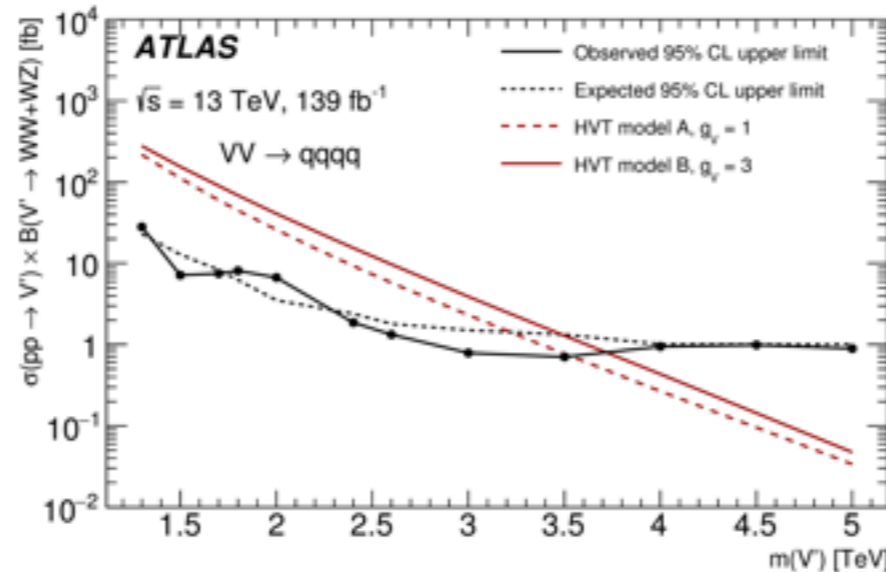
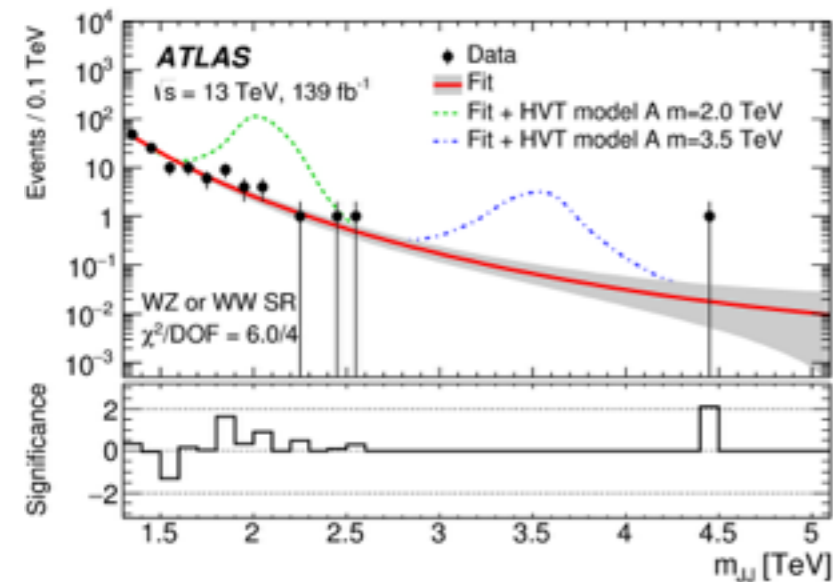


# “Dijet” —— $WW/WZ/ZZ$ Fully Hadronic decay



- Similar analysis performed in ATLAS using the **Full Run 2 data**
- Several improvements w.r.t Run 1 or 2016 analysis:
  - include track info in the Calorimeter based jets
  - include Jet mass and more powerful Jet substructure variables in the boosted boson finding

arXiv:1906.08589



**No obvious hint of bump above the falling SM background!**

**Exclude HVT  $W'/Z'$  with masses up to 3.8 TeV.**

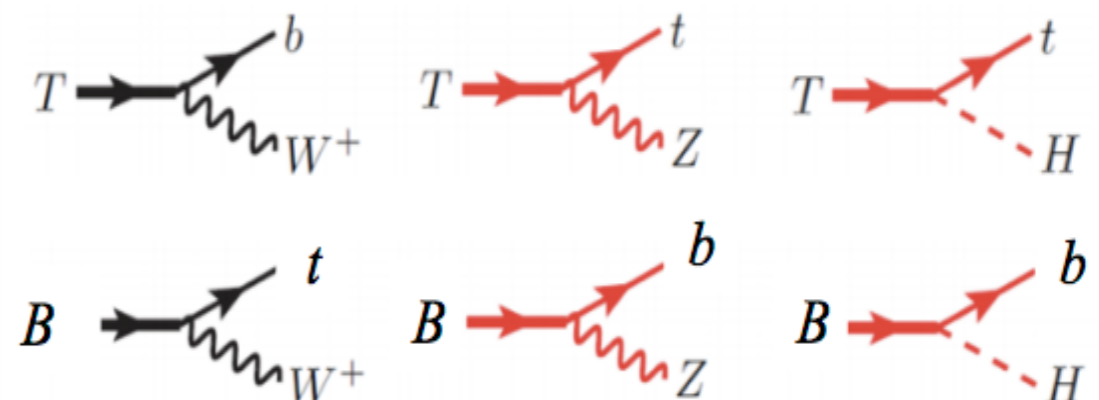
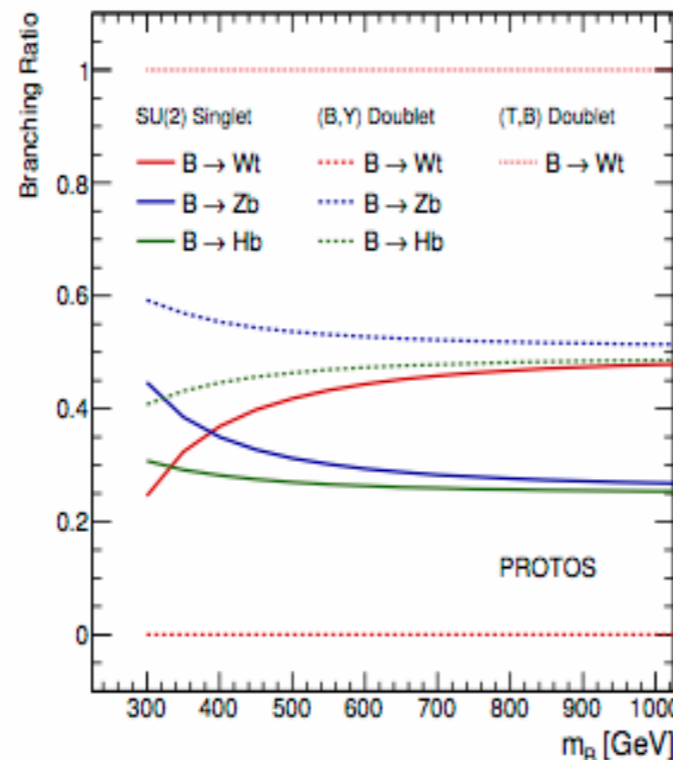
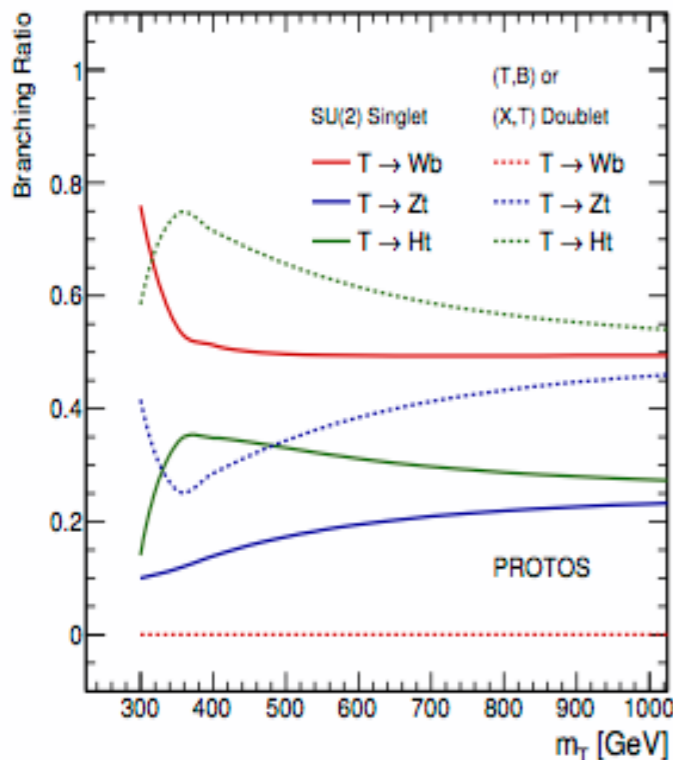
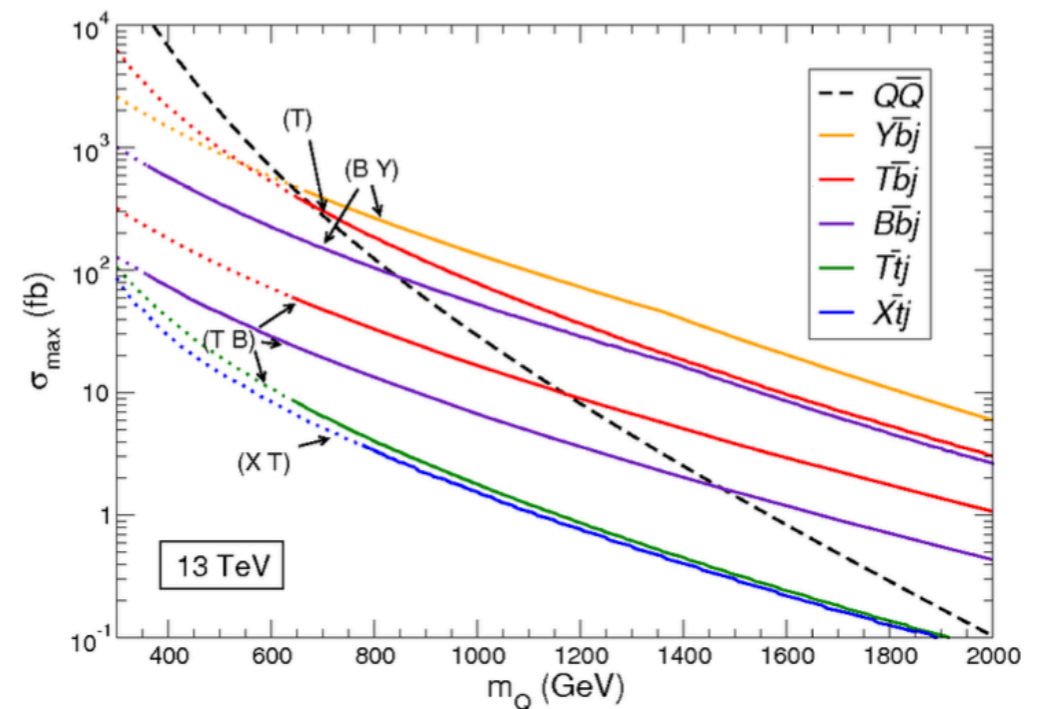
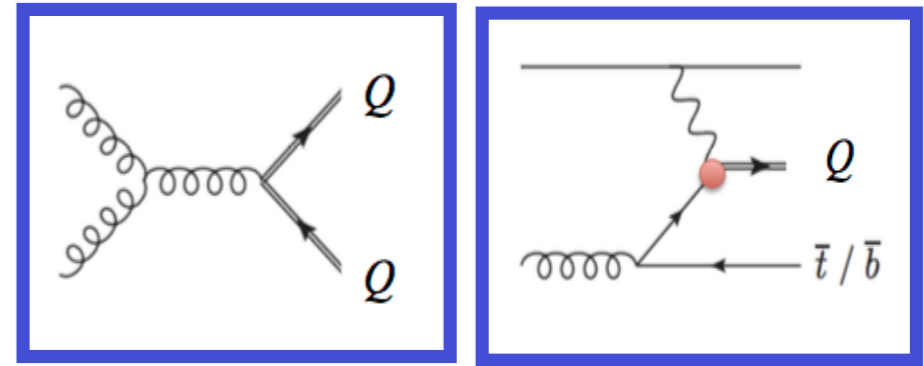
**Exclude Bulk RS Graviton with masses up to 1.8 TeV.**

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# **Vector-Like Quarks Search**

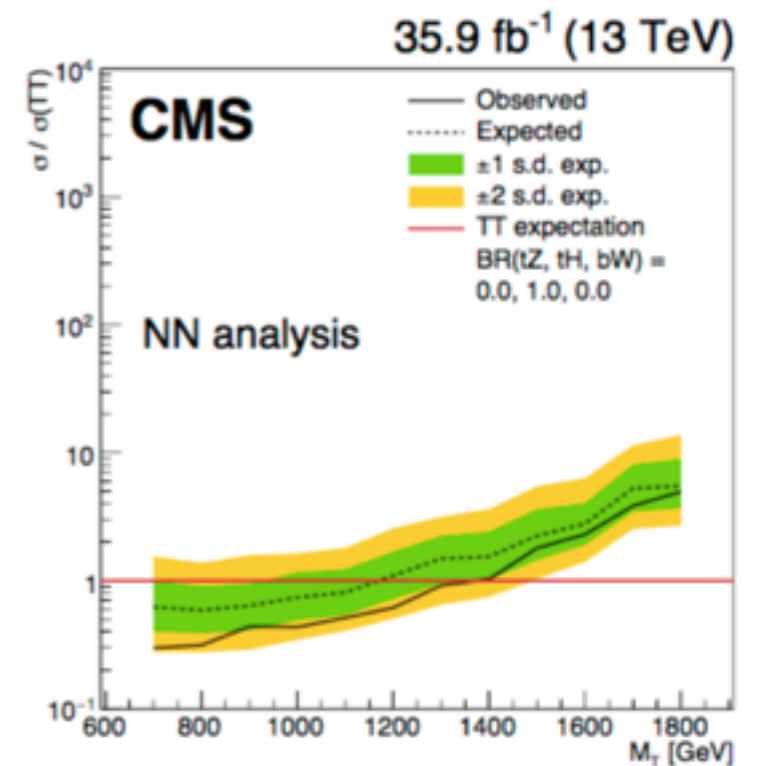
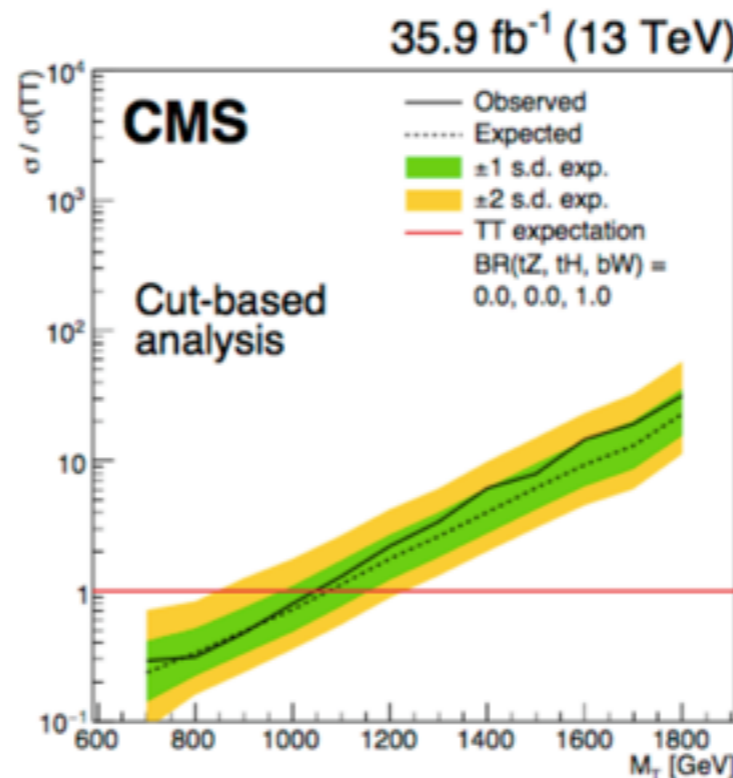
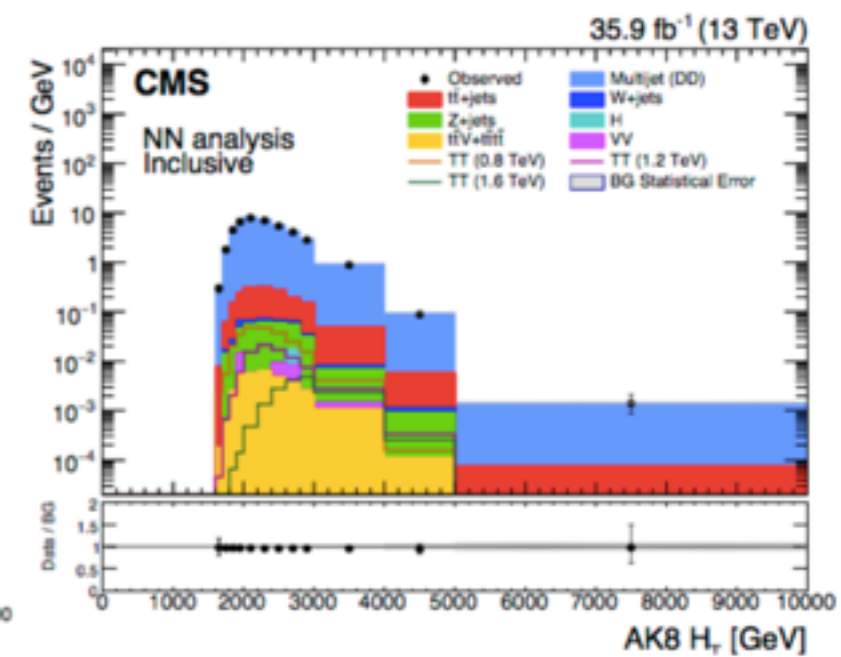
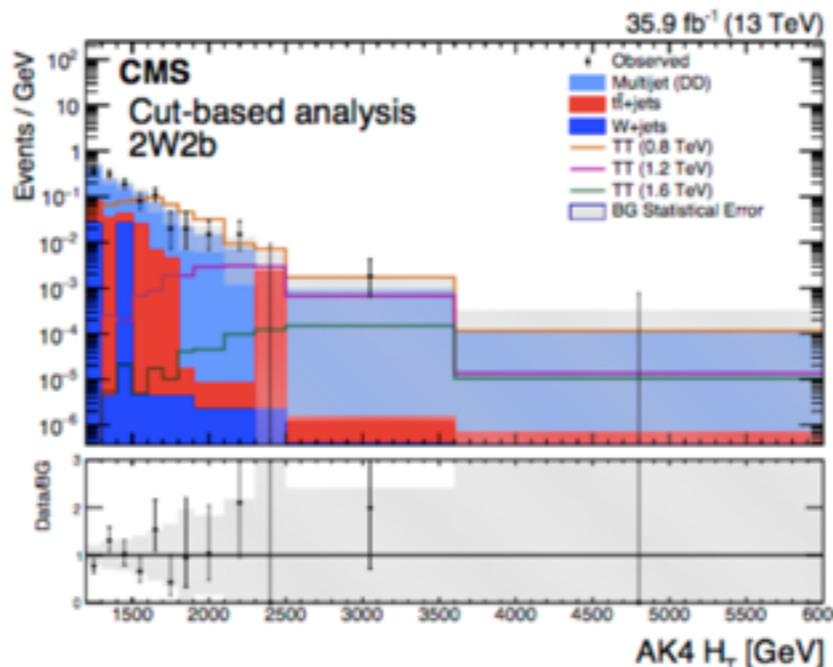
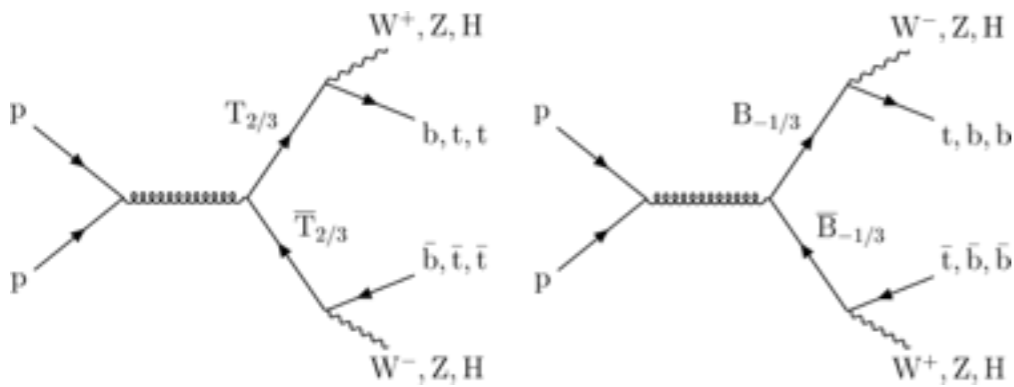
# Vector-Like Quarks

- Extra family of spin 1/2 quarks
  - symmetric vector-like coupling to W/Z
  - Mass from direct mass term
  - Can solve hierarchy problem
- Pair production from strong interaction
  - Model independent
- Single production from electroweak
  - Depends mixing with SM quarks
- Decays to boson+heavy quark



# Pair-Produced VLQ

CMS-PAS-B2G-18-005



Limit for  $M_T$  at 1040 GeV  
if  $BR(T \rightarrow Wb) = 1$

Limit for  $M_T$  at 1370 GeV  
if  $BR(T \rightarrow tH) = 1$

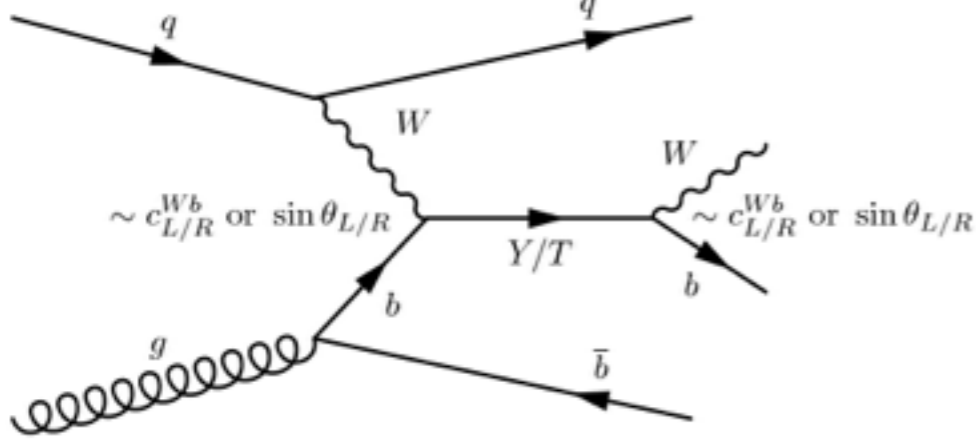
- Fully hadronic final states:

- requiring  $\geq 4$  jets

- Two independent searches:

- cut-based:  $TT \rightarrow WbWb$
- Neural-Network: boosted event shape tagger algorithm to identify jets from  $t, b, W, Z$  or  $H$ , account all  $TT, BB$  hadronic final states.

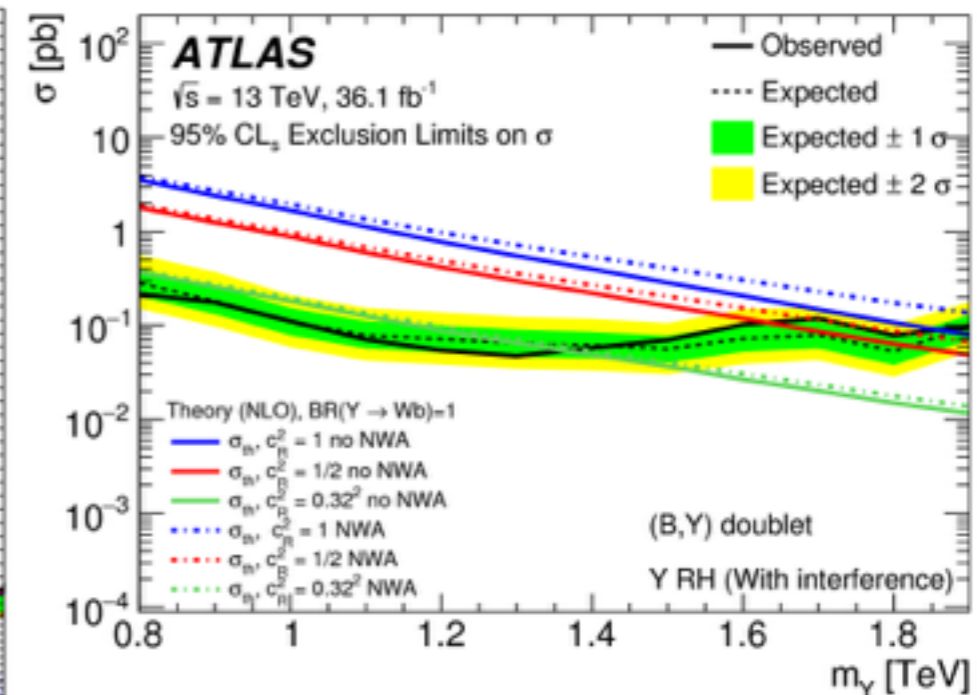
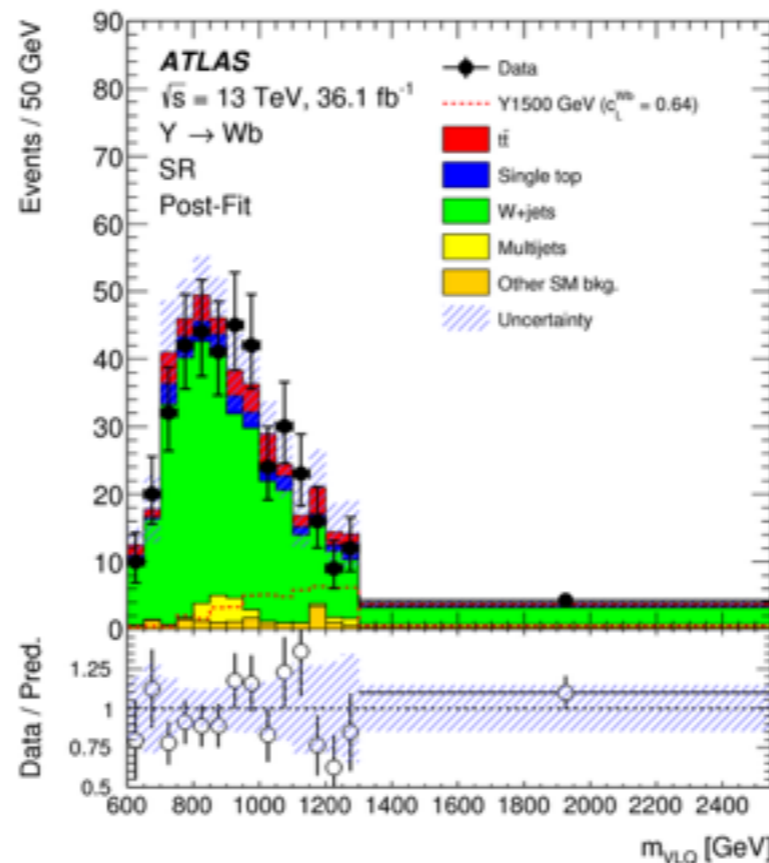
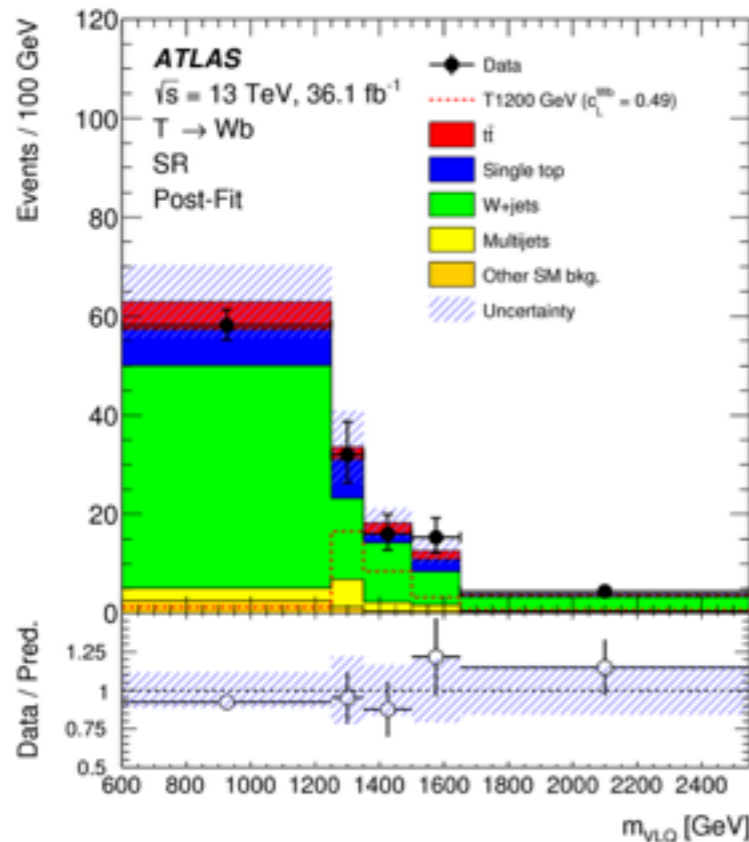
# Singly Produced VLQ



$$Y/T \rightarrow Wb \rightarrow l\nu b$$

JHEP 05(2019)164

- Vector-like T (+2/3) quarks can belong to any weak-isospin multiplet, while vector-like Y(-4/3) can not be singlets, only consider (B, Y) doublet or (T, B, Y) triplet in this analysis
- Singly production (strong interaction) probe the VLQ coupling with SM quarks as a function of VLQ mass
- Dominant backgrounds coming from: W+jets, Top, QCD, Z, multi-bosons



# Limits for Exotics Searches Up to 2019 May

## ATLAS Exotics Searches\* - 95% CL Upper Exclusion Limits

Status: May 2019

$\int \mathcal{L} dt = (3.2 - 139) \text{ fb}^{-1}$

ATLAS Preliminary

$\sqrt{s} = 8, 13 \text{ TeV}$

	Model	$\ell, \gamma$	Jets†	$E_T^{\text{miss}}$	$\int \mathcal{L} dt [\text{fb}^{-1}]$	Limit	Reference
Extra dimensions	ADD $G_{KK} + g/q$	$0 e, \mu$	$1-4 j$	Yes	36.1	$M_D$ 7.7 TeV	$n = 2$ 1711.03301
	ADD non-resonant $\gamma\gamma$	$2 \gamma$	-	-	36.7	$M_S$ 8.6 TeV	$n = 3 \text{ HLZ NLO}$ 1707.04147
	ADD QBH	-	$2 j$	-	37.0	$M_{\text{bh}}$ 8.9 TeV	$n = 6$ 1703.09127
	ADD BH high $\sum p_T$	$\geq 1 e, \mu$	$\geq 2 j$	-	3.2	$M_{\text{bh}}$ 8.2 TeV	$n = 6, M_D = 3 \text{ TeV, rot BH}$ 1606.02265
	ADD BH multijet	-	$\geq 3 j$	-	3.6	$M_{\text{bh}}$ 9.55 TeV	$n = 6, M_D = 3 \text{ TeV, rot BH}$ 1512.02586
	RS1 $G_{KK} \rightarrow \gamma\gamma$	$2 \gamma$	-	-	36.7	$G_{KK} \text{ mass}$ 4.1 TeV	$k/\overline{M}_{Pl} = 0.1$ 1707.04147
	Bulk RS $G_{KK} \rightarrow WW/ZZ$	multi-channel	-	-	36.1	$G_{KK} \text{ mass}$ 2.3 TeV	$k/\overline{M}_{Pl} = 1.0$ 1808.02380
	Bulk RS $G_{KK} \rightarrow WW \rightarrow qq\bar{q}\bar{q}$	$0 e, \mu$	$2 J$	-	139	$G_{KK} \text{ mass}$ 1.6 TeV	$k/\overline{M}_{Pl} = 1.0$ ATLAS-CONF-2019-003
	Bulk RS $G_{KK} \rightarrow tt$	$1 e, \mu$	$\geq 1 b, \geq 1J/2j$	Yes	36.1	$G_{KK} \text{ mass}$ 3.8 TeV	$\Gamma/m = 15\%$ 1804.10823
	2UED / RPP	$1 e, \mu$	$\geq 2 b, \geq 3 j$	Yes	36.1	$KK \text{ mass}$ 1.8 TeV	Tier (1,1), $\mathcal{B}(A^{(1,1)} \rightarrow tt) = 1$ 1803.09678
Gauge bosons	SSM $Z' \rightarrow \ell\ell$	$2 e, \mu$	-	-	139	$Z' \text{ mass}$ 5.1 TeV	$\Gamma/m = 1\%$ 1903.06248
	SSM $Z' \rightarrow \tau\tau$	$2 \tau$	-	-	36.1	$Z' \text{ mass}$ 2.42 TeV	1709.07242
	Leptophobic $Z' \rightarrow b\bar{b}$	-	$2 b$	-	36.1	$Z' \text{ mass}$ 2.1 TeV	1805.09299
	Leptophobic $Z' \rightarrow tt$	$1 e, \mu$	$\geq 1 b, \geq 1J/2j$	Yes	36.1	$Z' \text{ mass}$ 3.0 TeV	1804.10823
	SSM $W' \rightarrow \ell\nu$	$1 e, \mu$	-	Yes	139	$W' \text{ mass}$ 6.0 TeV	CERN-EP-2019-100
	SSM $W' \rightarrow \tau\nu$	$1 \tau$	-	Yes	36.1	$W' \text{ mass}$ 3.7 TeV	1801.06992
	HVT $V' \rightarrow WZ \rightarrow qq\bar{q}\bar{q}$ model B	$0 e, \mu$	$2 J$	-	139	$V' \text{ mass}$ 3.6 TeV	$g_V = 3$ ATLAS-CONF-2019-003
	HVT $V' \rightarrow WH/ZH$ model B	multi-channel	-	-	36.1	$V' \text{ mass}$ 2.93 TeV	$g_V = 3$ 1712.06518
	LRSM $W_R \rightarrow tb$	multi-channel	-	-	36.1	$W_R \text{ mass}$ 3.25 TeV	1807.10473
	LRSM $W_R \rightarrow \mu N_R$	$2 \mu$	$1 J$	-	80	$W_R \text{ mass}$ 5.0 TeV	$m(N_R) = 0.5 \text{ TeV, } g_L = g_R$ 1904.12679
CI	CI $qq\bar{q}\bar{q}$	-	$2 j$	-	37.0	$\Lambda$ 21.8 TeV	$\eta_{LL}$ 1703.09127
	CI $\ell\ell q\bar{q}$	$2 e, \mu$	-	-	36.1	$\Lambda$ 40.0 TeV	$\eta_{LL}$ 1707.02424
	CI $t\bar{t}t\bar{t}$	$\geq 1 e, \mu$	$\geq 1 b, \geq 1 j$	Yes	36.1	$\Lambda$ 2.57 TeV	$ C_{6t}  = 4\pi$ 1811.02305
DM	Axial-vector mediator (Dirac DM)	$0 e, \mu$	$1-4 j$	Yes	36.1	$m_{\text{med}}$ 1.55 TeV	$g_q=0.25, g_\nu=1.0, m(\chi) = 1 \text{ GeV}$ 1711.03301
	Colored scalar mediator (Dirac DM)	$0 e, \mu$	$1-4 j$	Yes	36.1	$m_{\text{med}}$ 1.67 TeV	$g=1.0, m(\chi) = 1 \text{ GeV}$ 1711.03301
	$VV_{\chi\chi}$ EFT (Dirac DM)	$0 e, \mu$	$1 J, \leq 1 j$	Yes	3.2	$M_\chi$ 700 GeV	$m(\chi) < 150 \text{ GeV}$ 1608.02372
	Scalar reson. $\phi \rightarrow t\bar{t}$ (Dirac DM)	$0-1 e, \mu$	$1 b, 0-1 J$	Yes	36.1	$m_\phi$ 3.4 TeV	$y = 0.4, \lambda = 0.2, m(\chi) = 10 \text{ GeV}$ 1812.09743
LQ	Scalar LQ 1 <sup>st</sup> gen	$1, 2 e$	$\geq 2 j$	Yes	36.1	LQ mass 1.4 TeV	$\beta = 1$ 1902.00377
	Scalar LQ 2 <sup>nd</sup> gen	$1, 2 \mu$	$\geq 2 j$	Yes	36.1	LQ mass 1.56 TeV	$\beta = 1$ 1902.00377
	Scalar LQ 3 <sup>rd</sup> gen	$2 \tau$	$2 b$	-	36.1	$LQ_3^+ \text{ mass}$ 1.03 TeV	$\mathcal{B}(LQ_3^+ \rightarrow b\tau) = 1$ 1902.08103
	Scalar LQ 3 <sup>rd</sup> gen	$0-1 e, \mu$	$2 b$	Yes	36.1	$LQ_3^+ \text{ mass}$ 970 GeV	$\mathcal{B}(LQ_3^+ \rightarrow t\tau) = 0$ 1902.08103
Heavy quarks	VLQ $TT \rightarrow Ht/Zt/Wb + X$	multi-channel	-	-	36.1	T mass 1.37 TeV	SU(2) doublet 1808.02343
	VLQ $BB \rightarrow Wt/Zb + X$	multi-channel	-	-	36.1	B mass 1.34 TeV	SU(2) doublet 1808.02343
	VLQ $T_{5/3} T_{5/3} T_{5/3} \rightarrow Wt + X$	$2(SS) \geq 3 e, \mu \geq 1 b, \geq 1 j$	Yes	36.1	$T_{5/3} \text{ mass}$ 1.64 TeV	$\mathcal{B}(T_{5/3} \rightarrow Wt) = 1, c(T_{5/3} Wt) = 1$ 1807.11883	
	VLQ $Y \rightarrow Wb + X$	$1 e, \mu \geq 1 b, \geq 1 j$	Yes	36.1	Y mass 1.85 TeV	$\mathcal{B}(Y \rightarrow Wb) = 1, c_R(Wb) = 1$ 1812.07343	
	VLQ $B \rightarrow Hb + X$	$0 e, \mu, 2 \gamma \geq 1 b, \geq 1 j$	Yes	79.8	B mass 1.21 TeV	$\kappa_B = 0.5$ ATLAS-CONF-2018-024	
VLQ $QQ \rightarrow WqWq$	$1 e, \mu \geq 4 j$	Yes	20.3	Q mass 690 GeV	1509.04261		
Excited fermions	Excited quark $q^* \rightarrow qg$	-	$2 j$	-	139	$q^* \text{ mass}$ 6.7 TeV	only $u^*$ and $d^*$ , $\Lambda = m(q^*)$ ATLAS-CONF-2019-007
	Excited quark $q^* \rightarrow q\gamma$	$1 \gamma$	$1 j$	-	36.7	$q^* \text{ mass}$ 5.3 TeV	only $u^*$ and $d^*$ , $\Lambda = m(q^*)$ 1709.10440
	Excited quark $b^* \rightarrow b\bar{g}$	-	$1 b, 1 j$	-	36.1	$b^* \text{ mass}$ 2.6 TeV	1805.09299
	Excited lepton $\ell^*$	$3 e, \mu$	-	-	20.3	$\ell^* \text{ mass}$ 3.0 TeV	$\Lambda = 3.0 \text{ TeV}$ 1411.2921
	Excited lepton $\nu^*$	$3 e, \mu, \tau$	-	-	20.3	$\nu^* \text{ mass}$ 1.6 TeV	$\Lambda = 1.6 \text{ TeV}$ 1411.2921
Other	Type III Seesaw	$1 e, \mu$	$\geq 2 j$	Yes	79.8	$N^0 \text{ mass}$ 560 GeV	$m(W_R) = 4.1 \text{ TeV, } g_L = g_R$ ATLAS-CONF-2018-020
	LRSM Majorana $\nu$	$2 \mu$	$2 j$	-	36.1	$N_R \text{ mass}$ 3.2 TeV	1809.11105
	Higgs triplet $H^{\pm\pm} \rightarrow \ell\ell$	$2, 3, 4 e, \mu$ (SS)	-	-	36.1	$H^{\pm\pm} \text{ mass}$ 870 GeV	DY production 1710.09748
	Higgs triplet $H^{\pm\pm} \rightarrow \ell\tau$	$3 e, \mu, \tau$	-	-	20.3	$H^{\pm\pm} \text{ mass}$ 400 GeV	DY production, $\mathcal{B}(H^{\pm\pm} \rightarrow \ell\tau) = 1$ 1411.2921
	Multi-charged particles	-	-	-	36.1	multi-charged particle mass 1.22 TeV	DY production, $ q  = 5e$ 1812.03673
	Magnetic monopoles	-	-	-	34.4	monopole mass 2.37 TeV	DY production, $ g  = 1g_D, \text{ spin } 1/2$ 1905.10130

$\sqrt{s} = 8 \text{ TeV}$   $\sqrt{s} = 13 \text{ TeV}$  partial data  $\sqrt{s} = 13 \text{ TeV}$  full data

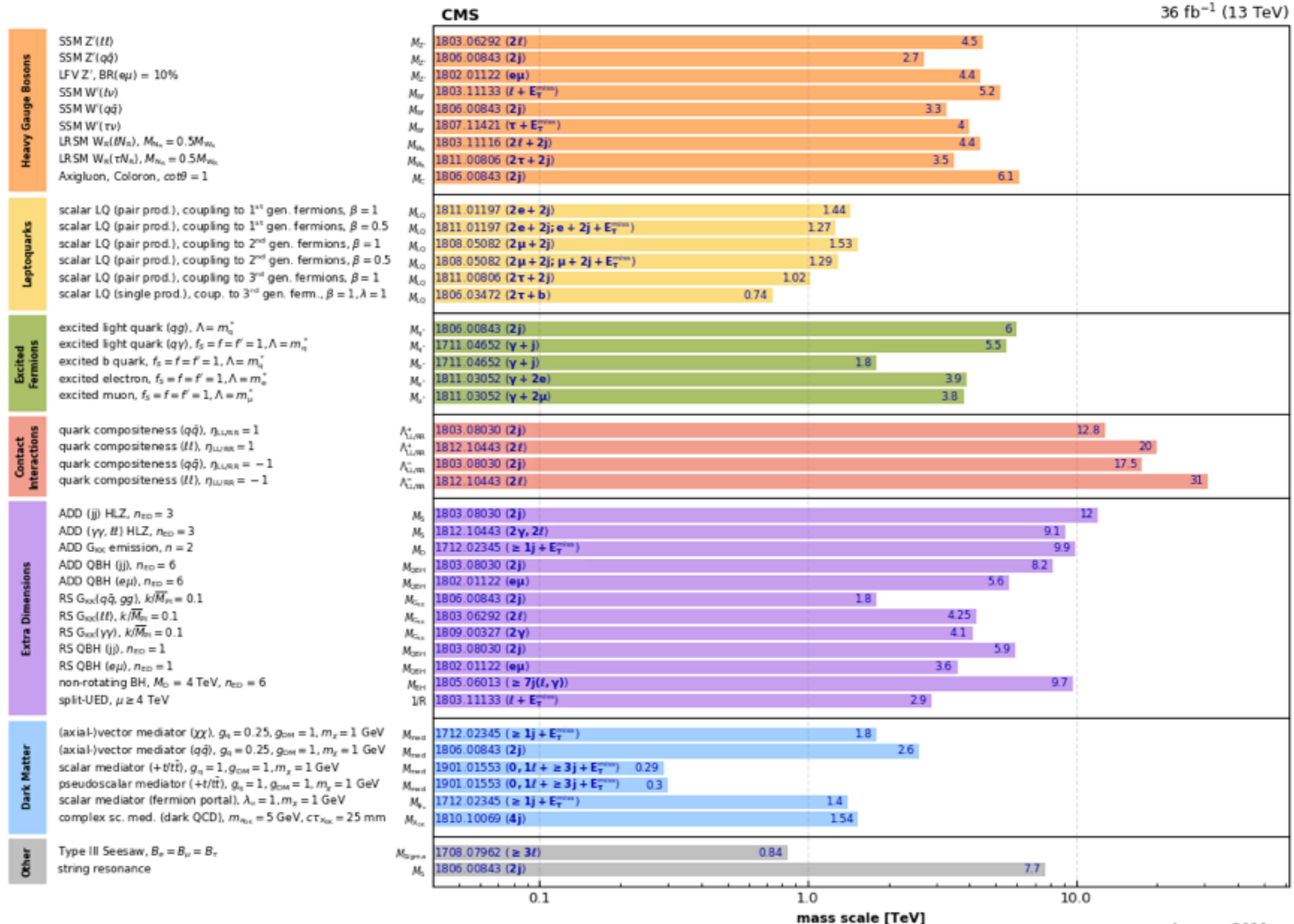
10<sup>-1</sup> 1 10 Mass scale [TeV]

\*Only a selection of the available mass limits on new states or phenomena is shown.

†Small-radius (large-radius) jets are denoted by the letter j (J).

# Limits for Exotics Searches based on 2016 Data

## Overview of CMS EXO results



Selection of observed exclusion limits at 95% C.L. (theory uncertainties are not included).

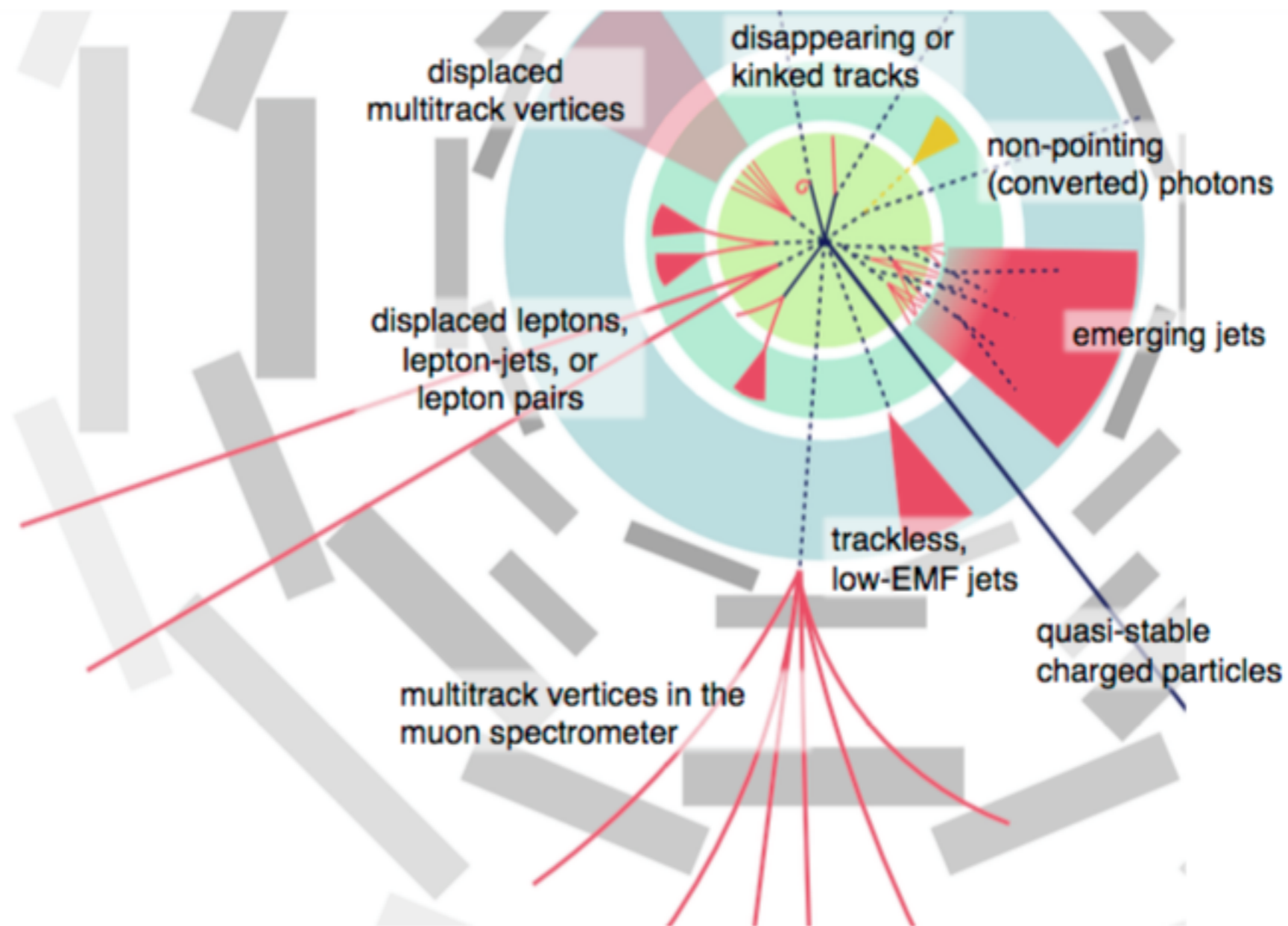
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# Long-lived Particle Search

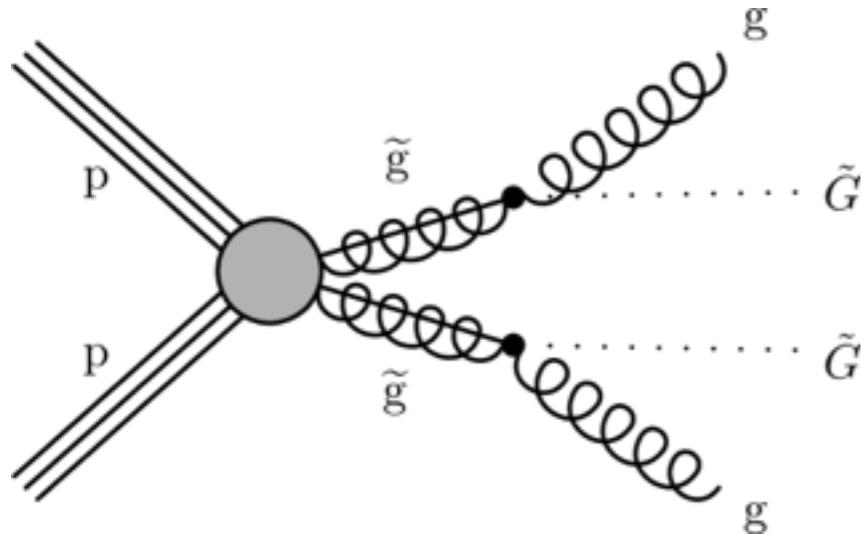


# Long-Lived Particles

- BSM particles may have lifetime that are long compared to SM particles, referred as Long-Lived particles (LLP), will decay far from interaction point.
- Search for LLP requires for customised techniques to identify displaced vertices.



# Displaced Jet + MET

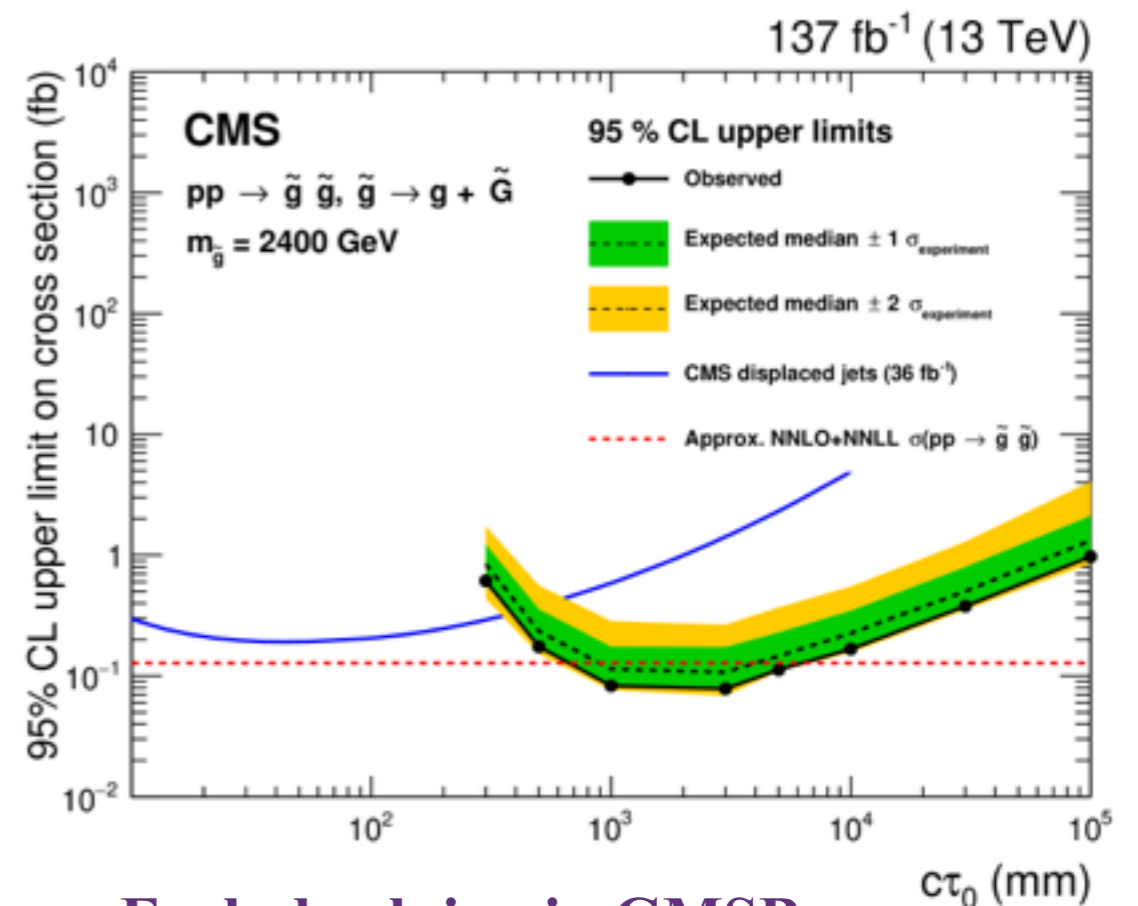
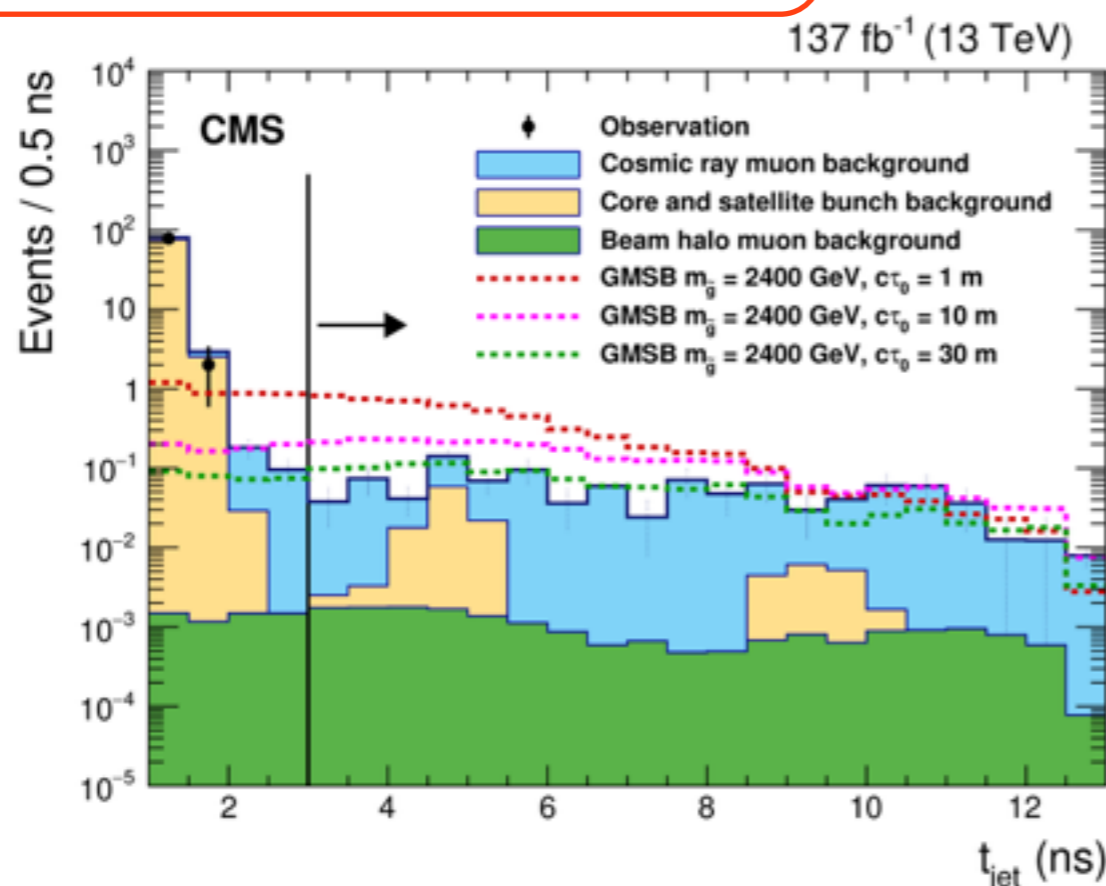


- Several models can predict such signature: Gauge-mediated SUSY breaking (GMSB), split and stealth SUSY, hidden valley models

- The first time to use timing capability of ECAL (in CMS) to identify the displaced jet

- SR:  $3\text{ns} < t_{\text{jet}} < 20\text{ns}$

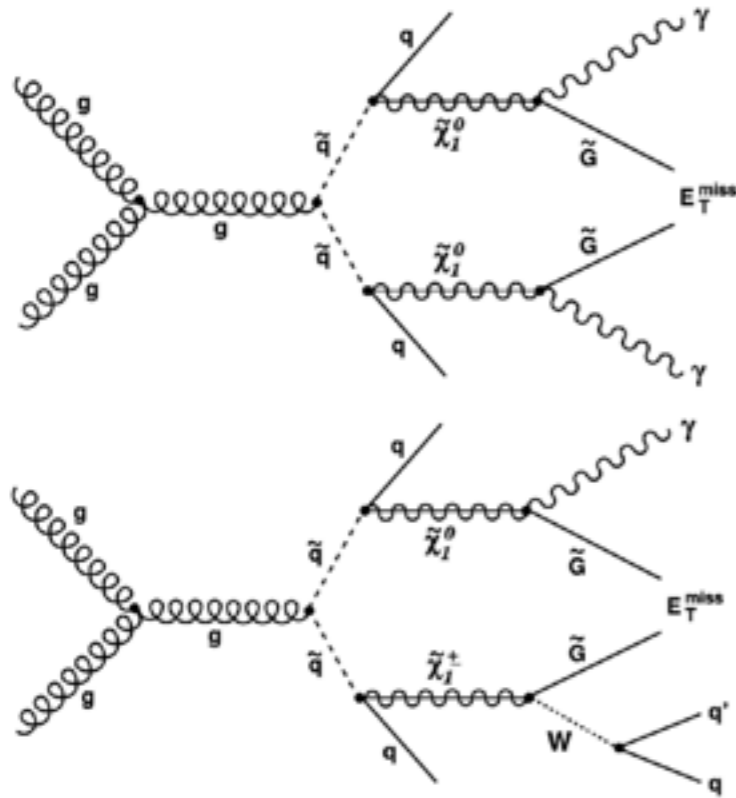
Phys. Lett. B 797 (2019) 134876



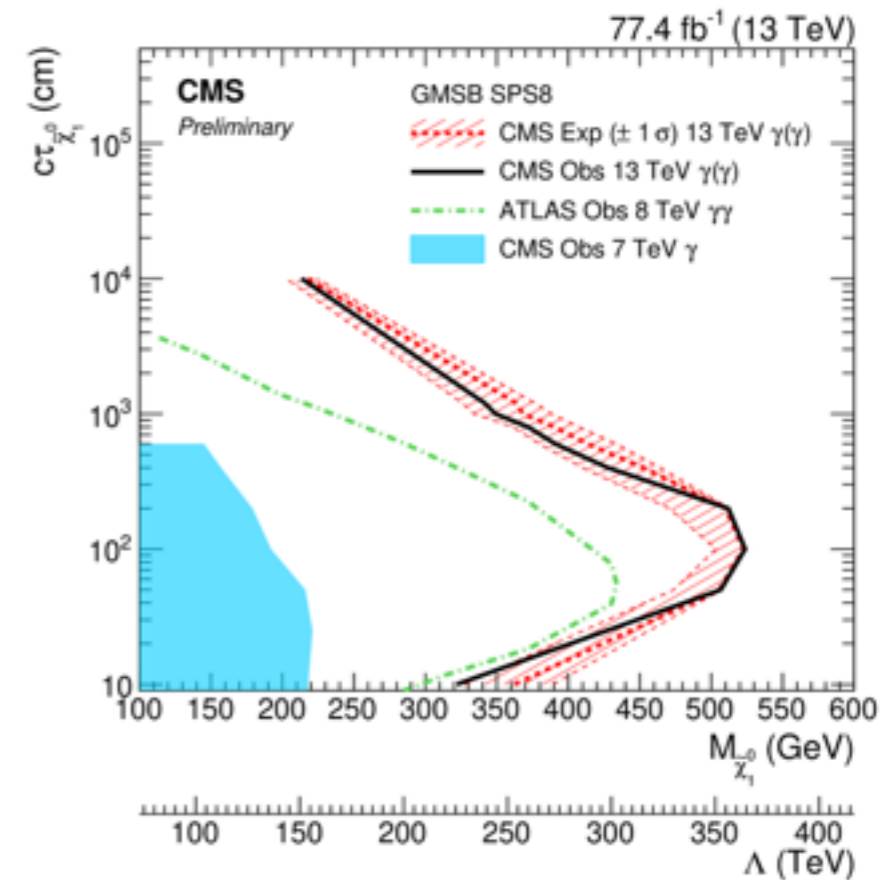
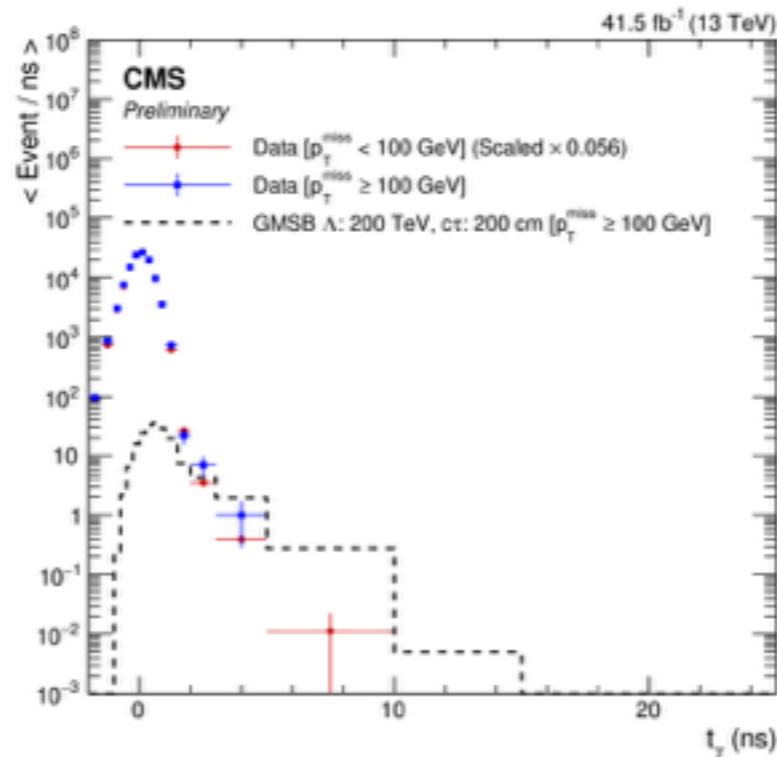
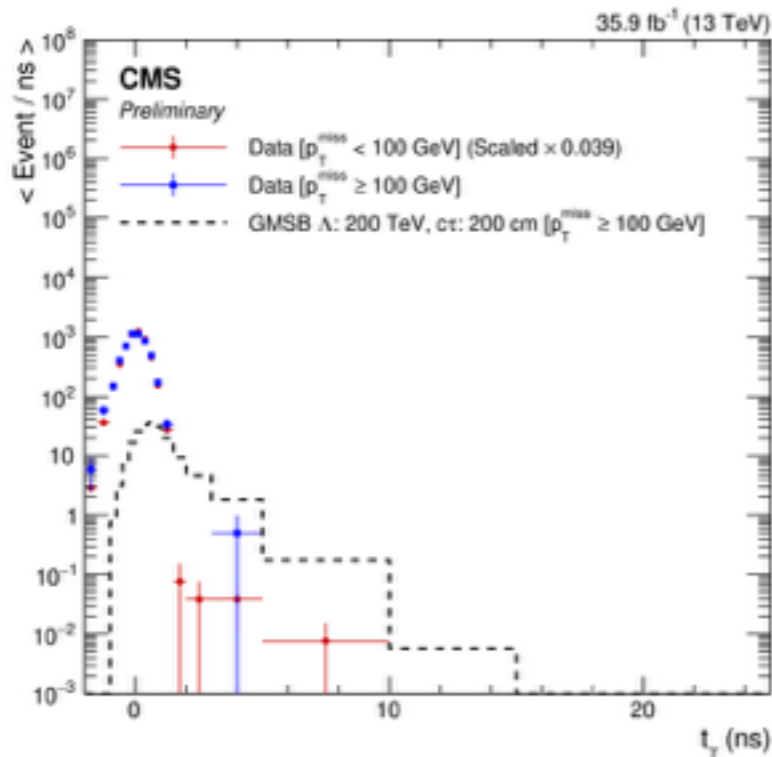
No events observed in SR:  $3\text{ns} < t_{\text{jet}} < 20\text{ns}$ . Exclude gluino in GMSB with mass of 2.1 TeV, 2.5 TeV and 1.9 TeV for  $c\tau$  of 0.3m, 1m and 100m respectively.

# Displaced Photon

- Also test on benchmark model (GMSB)
- Requiring one or two photon with displaced vertex and three or more jets in the events.
- diphoton trigger for 2016 data, dedicated single photon trigger (designed for displaced photons) used in 2017 data.



CMS-PAS-EXO-19-005



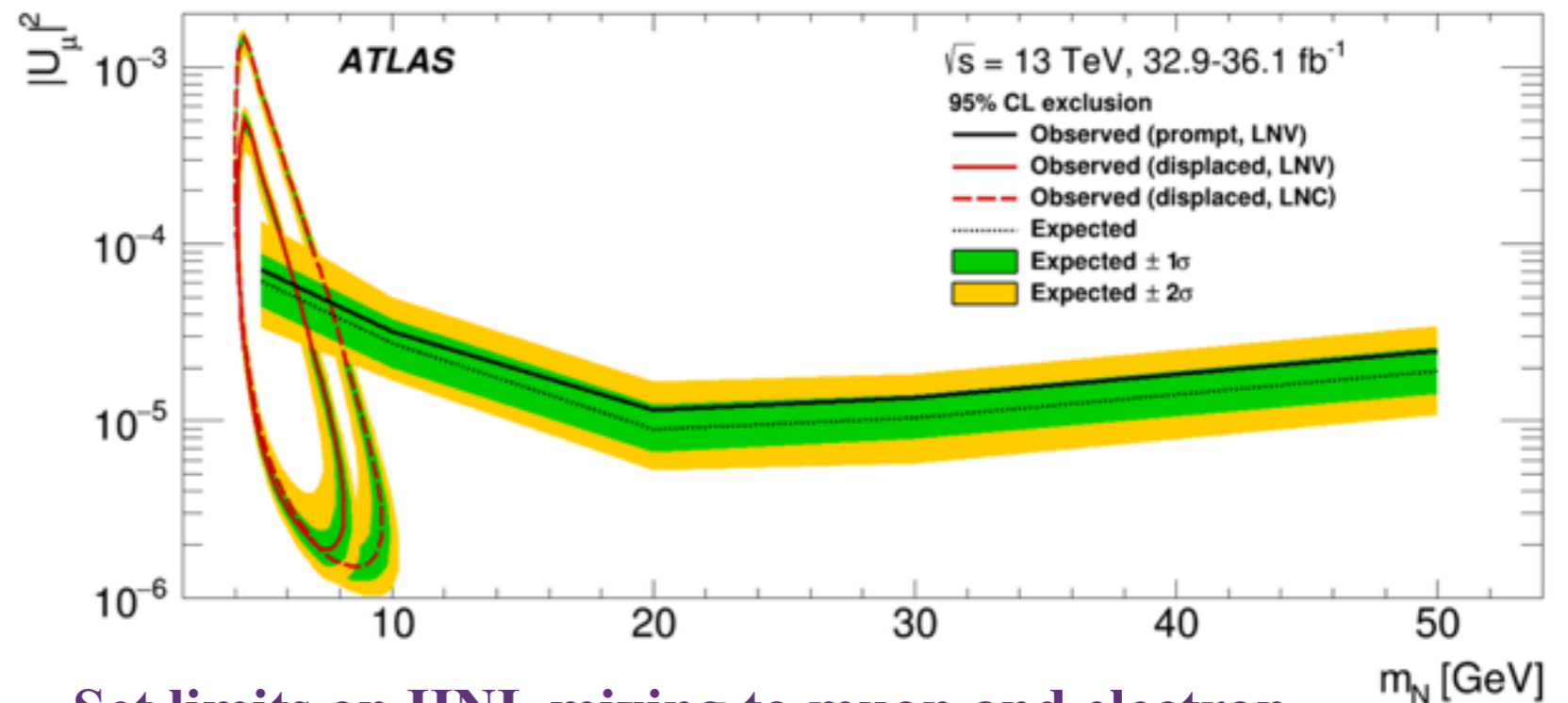
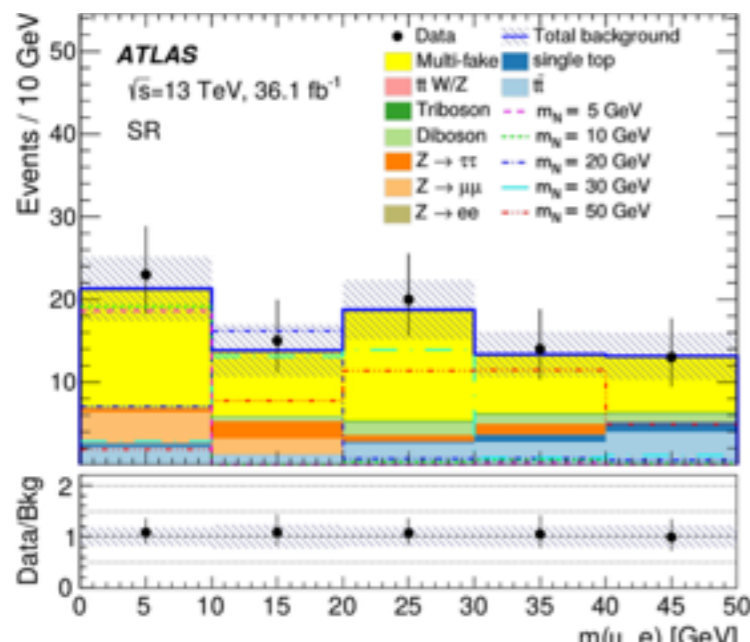
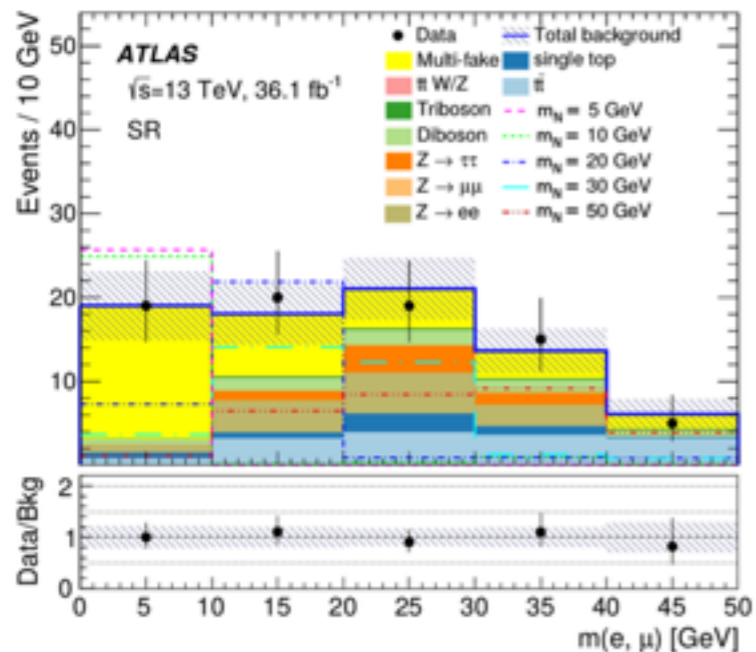
No sign observed for displaced Photon.

Significantly extend the limits in the 2D plane of  $c\tau$  vs mass of neutralino.

# Search for Heavy Neutral Lepton

- Heavy neutrino: can explain neutrino mass, matter-antimatter asymmetry, DM
- Search with both prompt and displaced signatures
- Signals include:  $e^\pm e^\mp \mu^\pm$  or  $\mu^\pm \mu^\mp e^\pm$  with small MET
- **First displaced search featured with a prompt muon accompanies by a displaced vertex from two OS leptons**

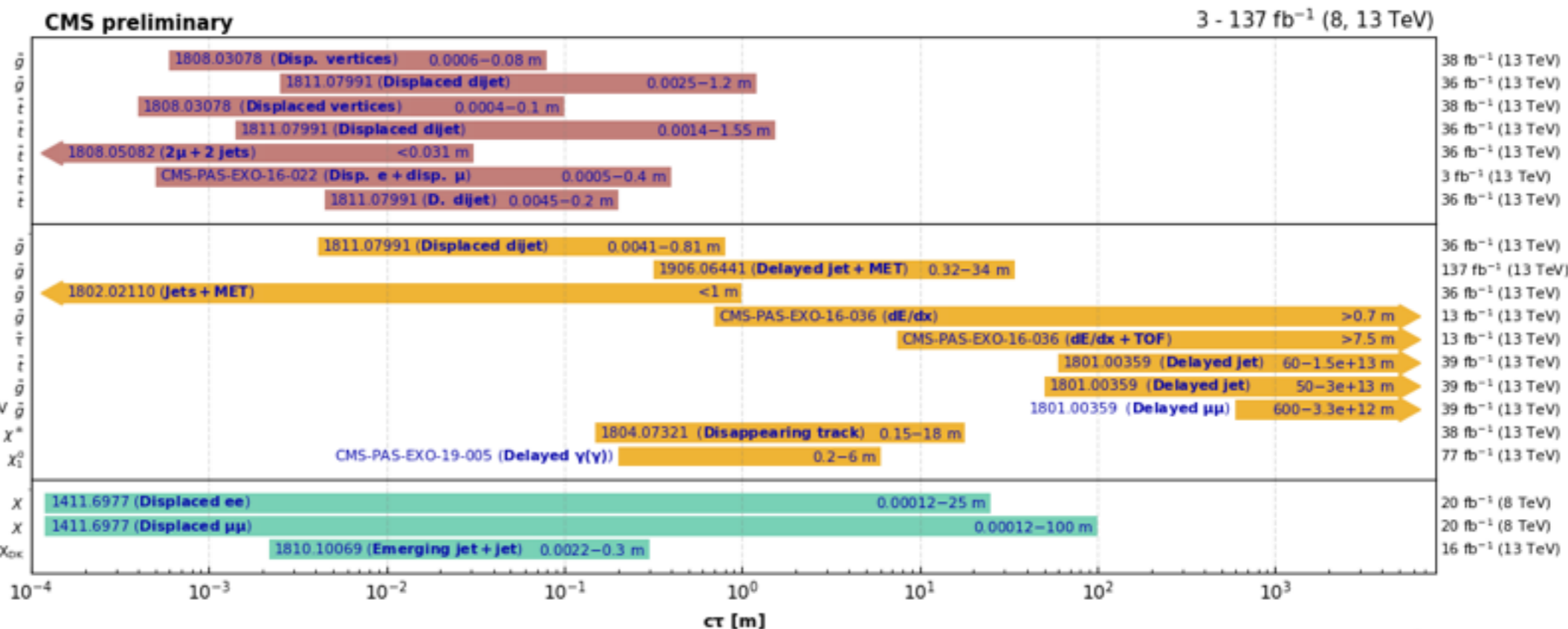
arXiv:1905.09787



Set limits on HNL mixing to muon and electron neutrinos for HNL masses in the range 4.5–50 GeV.

# Limits for Long-Lived Particles

## Overview of CMS long-lived particle searches



Selection of observed exclusion limits at 95% C.L. (theory uncertainties are not included). The y-axis tick labels indicate the studied long-lived particle.

July 2019

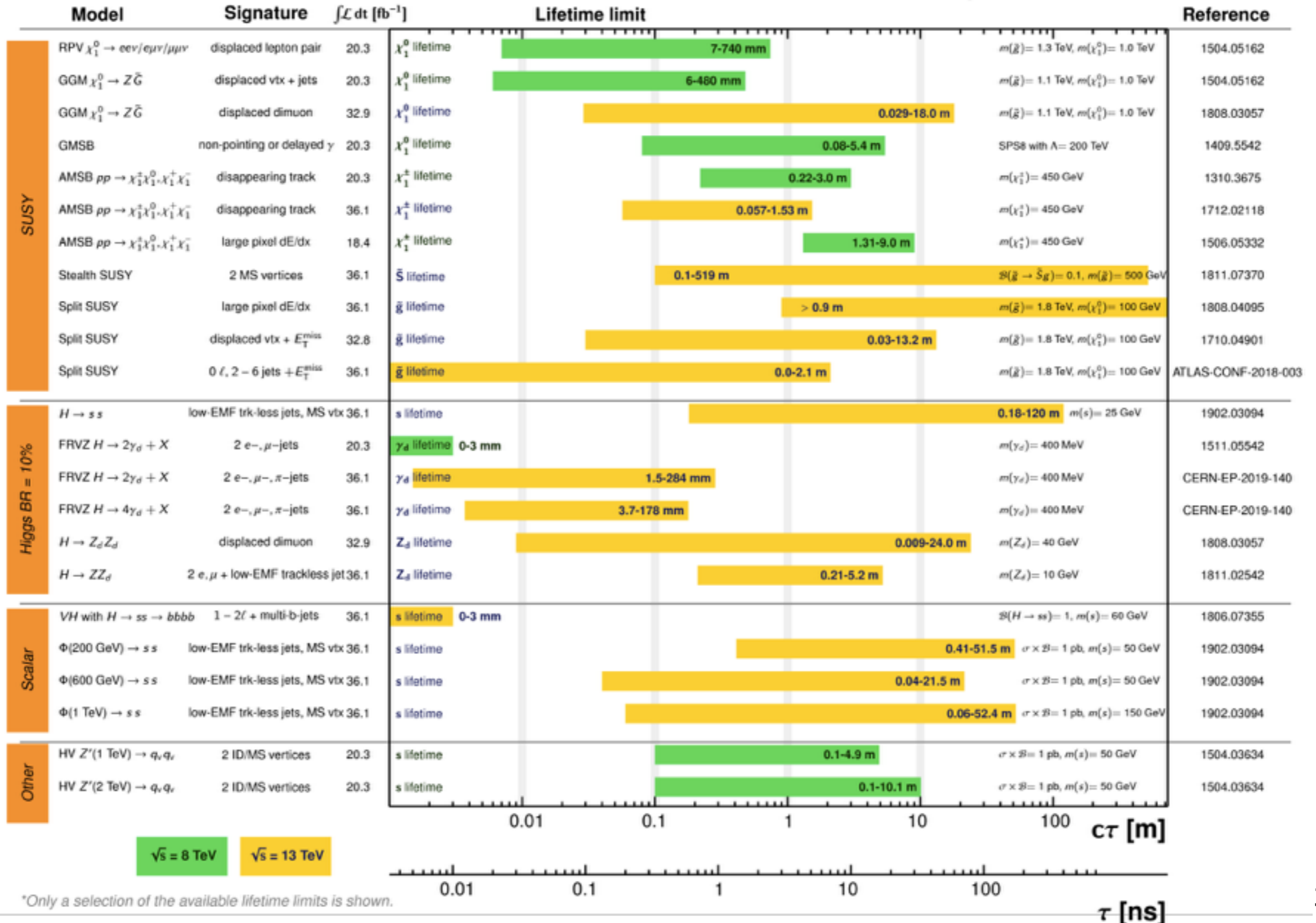
# Limits for Long-Lived Particles

## ATLAS Long-lived Particle Searches\* - 95% CL Exclusion

Status: July 2019

ATLAS Preliminary

$$\int \mathcal{L} dt = (18.4 - 36.1) \text{ fb}^{-1} \sqrt{s} = 8, 13 \text{ TeV}$$



\*Only a selection of the available lifetime limits is shown.

# Conclusion

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- **Very Active field in the Exotics or other BSM searches**
  - probing various models beyond SM
  - developing new techniques to improve analysis sensitivity
  - combination of various channels
- **Early analyses with full Run 2 data performed**
  - dilepton, dijet, lepton + neutrino, displaced jet + MET ...
  - No sign for new physics found yet!
- **Lots of analyses are on-going, stay-tuned for more exciting results!**
- **Surprise(s)** may be hidden somewhere!



- 
- backup